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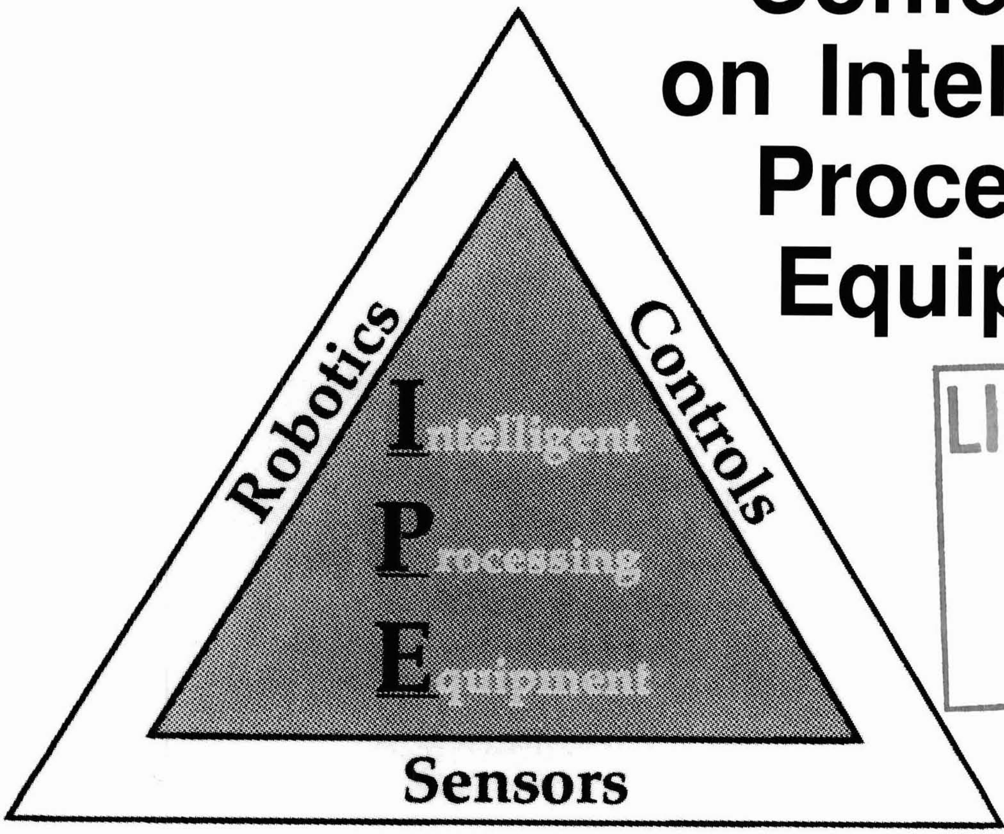
NASA Conference Publication 3138

The Federal Conference on Intelligent Processing Equipment



Advanced Manufacturing Technology

Proceedings of a conference held at
San Jose Convention Center
San Jose, California
December 3–5, 1991

NASA

Held concurrently with

NASA Conference Publication 3138

The Federal Conference on Intelligent Processing Equipment

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NASA
National Aeronautics and
Space Administration
Office of Management
Scientific and Technical
Information Program
1992

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EXECUTIVE SUMMARY

Synopsis of Intelligent Processing Equipment Efforts

In May of last year, the Federal Coordinating Council for Science, Engineering, and Technology, through their Committee on Industry and Technology, established a new initiative and a Steering Group on Advanced Manufacturing with then NASA Deputy Administrator J.R. Thompson as Chairman.

The Steering Group selected Intelligent Processing Equipment, one of the four critical manufacturing technologies of advanced manufacturing, for their first initiative. The Steering Group also formed an inter-agency working team, under the chairmanship of Mr. Robert J. Schwinghamer**, to collect descriptive information applicable to Intelligent Processing Equipment (specifically sensors, robotics, and controls) from the development efforts of all participating Federal Agencies and present this technology to industry before the end of 1991. A briefing to industry of this material was accomplished on December 3-5, 1991 at the San Jose (CA) Convention Center.*

The material was presented by participating Federal organizations in four sessions on Tuesday and Wednesday (December 3 and 4), as shown in the attached Symposium brochure. A key element planned by the working team was an invited panel of eleven top industry leaders involved in advanced manufacturing (names and organizations on subsequent page). This panel attended the agency briefing sessions and then, on Thursday, December 5, discussed this technology material including suggestions to improve the technology transfer process. A luncheon was also held at the convention center on Thursday, with Mr. Tom Murrin (Dean, School of Business Administration at Duquesne University and member of President Bush's Council of Advisors) as speaker. The subject of Mr. Murrin's address was "The National Competitiveness" which was relevant to the papers on their IPE related technology, and the industry review panel discussions, along with their major points abstracted by each panel member.

In addition to the government technology briefings and industry panel discussions, a number of Federal Agencies arranged displays with demonstrations and personal discussions running concurrent with NASA's Technology 2001 symposium. This provided additional information and coordination for transfer of agency technology to industry.

The three-day IPE conference, and this document containing the presented IPE technology material with the Industry review panel transactions and abstracted major points, concludes the actions assigned to the IPE Inter-Agency Working Team last June.

** From the "National Critical Technologies Panel Report to the President," March 1991.*
*** Deputy Director for Space Transportation Systems of the NASA Marshall Space Flight Center Science and Engineering Directorate.*

IPE Conference Program

Conference Chairman: Robert J. Schwinghamer,
Marshall Space Flight Center, NASA

Tuesday, December 3

Room A3

Technical Session
1:00 pm - 3:00 pm

Moderator: Dr. Suren Rao,
National Science Foundation

1:00 **Department of Agriculture**
Dr. Ruxton Villet, National Program Leader, Product Utilization, Agricultural Research Service

1:30 **Department of Commerce**
Roger Kilmer Manufacturing Engineering Lab, National Institute of Standards and Technology

2:00 **Department of Energy**
Rick Peavy, Physical Scientist, Defense Programs Technology Transfer Div.

2:30 **Environmental Protection Agency**
Dan Greathouse, Operations Research Analyst

Room A3

Technical Session
4:30 pm - 6:00 pm

Moderator: Dan Greathouse,
Environmental Protection Agency

4:30 **Federal Emergency Management Agency**
Anne Marie Suprise, Industrial Specialist

5:00 **National Aeronautics and Space Administration**
Clyde Jones, Materials Engineer, Marshall Space Flight Ctr.

Wednesday, December 4

Room A3

Technical Session
8:30 am - 10:30 am

Moderator: Dr. Ruxton Villet,
Department of Agriculture

8:30 **National Institutes of Health**
Dr. Caroline Holloway, Director, Office of Science and Policy

9:00 **National Science Foundation**
Dr. Suren Rao, Program Director, Div. of Design and Manufacturing

9:30 **Department of the Air Force**
Captain Paul Sampson, Program Mgr., Machine Tools, Processing and Fabrication Div.

10:00 **Department of the Army**
Stanley Kopacz, Physicist, Picatinny Arsenal

Room A3

Technical Session
1:00 pm - 3:30 pm

Moderator: Anne Marie Suprise,
Federal Emergency Management Agency

1:00 **Department of the Navy**
Dr. Phillip Nanzetta, Dept. of Commerce, NIST

2:00 **Defense Logistics Agency**
Donald F. O'Brien Industrial Engineer, Manufacturing Engineering Research Office

2:30 **Strategic Defense Initiative Organization**
Greg Stottlemyer, Director, Producibility and Manufacturing

3:00 **Manufacturing Technology Information Analysis Center**
Michal Safar, Director, MTIAC

Thursday, December 5

Room A3

Industry Review Panel
8:00 am - 11:0-0 am

Rick Davis,
Panel Chairman
President and General Manager,
Martin Manned Space
Panelists:
Robert Becker, President, In Tolerance Corp.
Dr. Hadi Akeel
Vice President & Chief Engineer
General Motors-FANUC Robotics

Dr. Charles Hamermesh, Technical Director, SAMPE
Steven Scarborough, Manager of Control Systems, Honeywell Sensor and System Div.
Dick S. Lopatka
Assistant Director of Research
United Technologies Research Center
Bruce Brock, Vice President of Corporate Quality, Manufacturing, and Materials
Honeywell Inc.
Michael Cronin,
Chairman of the Board,
Automatix Inc.

IPE Luncheon
11:30 am - 1:00 pm

Speaker: Thomas J. Murrin, Dean, Duquesne Univ. School of Business and Administration; formerly Deputy Secretary, US Dept. of Commerce

INTELLIGENT PROCESSING EQUIPMENT (IPE) INTERAGENCY ADVANCED MANUFACTURING SYMPOSIUM

Interagency Working Team Members

NAME	ORGANIZATION
Bob Schwinghamer	NASA - Team Leader
Ruxton Villet	USDA
Ted Lettes	DOC
Lloyd Lehn	DOD
Rick Peavy	DOE
Alfred Galli	EPA
Anne Marie Suprise	FEMA
Fred Schottman	DOI/Bureau of Mines
Len Ault	NASA/Headquarters
Murray Eden	NIH
Caroline Holloway	NIH
Suren Rao	NSF
David Gold	OMB
Leo Macklin	OSTP
Paul Schuerer	NASA/Marshall Space Flight Center

STAFF

Jim Bain	NASA/Headquarters
John Pfeiffer	OMB/ESD
Bill Schnirring	NASA Tech Briefs Magazine
Bob Middleton	NASA/Marshall Space Flight Center

INTELLIGENT PROCESSING EQUIPMENT (IPE) INTERAGENCY ADVANCED MANUFACTURING SYMPOSIUM

Industry Review Panel Members

Chair: Mr. Ric Davis
President and General Manager
Martin Marietta Aerospace
P.O. Box 29304
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126 29th St. Drive
Cedar Rapids, IA 52403-1407

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Mr. Michael Cronin
Chairman of the Board
Automatix, Inc.
755 Middlesex Turnpike
Billerica, MA 01821

Major Points from Industry Panel Review Discussion

The Federal Conference on Intelligent Processing Equipment conducted an Industry Panel Review Discussion. The panel consisted of ten top industry leaders involved in advanced manufacturing (names and organizations on subsequent page).

After attending agency briefings and symposia sessions, the panel convened on Thursday, December 5, 1991, to discuss the technology material and offered their suggestions on how to improve the technology transfer process. The panel was asked to respond to three questions regarding Intelligent Processing Equipment: 1) Why isn't U.S. developing it faster? 2) Why isn't U.S. using what we already have? and, 3) How can Federal R&D and technology transfer be improved to address these problems?

The following are major points from each panelist involved in the discussion. A complete transcript of the panel discussion can be found in Section II of this document.

Industry Panel Questions Regarding Intelligent Processing Equipment

- Why isn't U.S. developing it faster?
- Why isn't U.S. using what we already have?
- How can Federal R&D and Technology Transfer be improved to address these problems?

IPE Conference
Industry Review Panel Major Points

Hadi Akeel:

- Government sponsored research will effectively enhance the country's competitiveness only when general manufacturing industries can decide the direction and objectives of the research.

- U.S. robotics industry started with a bang in the 70's, fizzled in the 80's, and is now facing oblivion in the 90's.

- The government labs should identify who the customers of their technology are. If general industry is a customer then that customer should be a participant in the development process (provide input requirements, review progress, etc.)

- How much of the government agencies charter involves increasing industry's technology base? How much is it stressed? By their leadership? How much must be kept in the mind of the project team and those who decide the success or failure of the project? This process is very well recognized in the industry by those who have to live, or die, by the success of their project. They make money when things go right and risk their livelihood if things don't go right.

- If the government follows a similar process to industry development, then we may end up with the kind of development industry needs.

Ric Davis:

- Academia should be charged with introducing the new technology into their curriculum and also with teaching to graduates the sources of information that exists and the process used to access the data.

- Reduce the cost of accessing/applying the new technology to zero for small firms and nominal costs for the larger companies. Government costs could be recovered by <u>modest</u> royalties attached to successful transfers.

- Encourage the "secondary industry" that is emerging to help the end user access the information. This "secondary industry" ranges from newspapers to consultants and to a national society.

- Motivate government researchers and agencies to increase technical transfers for their work. Measure the amount of their personal time spent in such activities. Recognize and reward outstanding efforts by individuals and agencies.

- Ensure that regulations/legislations do not prevent transfer of technology. Lessons learned about how to work issues (such as patent rights, royalties, tax implications of help received, etc.) need to be disseminated.

- Resources would be better spent on ensuring cost effective access to the multiple databases that exist than on creating a new single database. As each database evolves, modify it with cost effective access in mind.

Ric Davis (cont'd):

- Give a grant to one or more universities to define a program to accomplish Recommendation #1 and to publish and update a manual that identifies all the potential sources of information and directions on how to tax those resources.

- Charge the National Societies with the responsibility to create interest in their memberships in the technology transfer process. Reward those Societies that are successful.

Vern Solberg:

- There should be an agency or team that can go out and help the small business person. It is the little person who can't get the prime rate loans, doesn't have engineering resources to develop technology or understand agency technology.

- We are one of the largest contract manufacturers in the country and we rely on small guys to supply us, but a lot of them are going out of business. We are losing them and good share support.

- The statement heard a lot, "Well, I guess we can go offshore if we want to be competitive" is how we lose most of our technology.

Bruce Brock:

- Government R&D must be linked closely with this country's industrial needs.

- The Government laboratories do not coordinate their work; therefore, a huge percentage of technology is redundantly developed.

- Budgets for R&D laboratories should be tied with proven and measurable technology deployment to industry.

- Performance measures are needed that can demonstrate that the R&D labs are making their goals -- there appears to be none!

- The Government needs to respond to or implement the recommendations of the Council on Competitiveness.

- The U.S. should recognize that the rules of the economic world have changed and that we (the U.S.) must change its internal laws and rules to allow it to compete in the game (i.e., economic) fairly.

Steven E. Scarborough:

- The United States has a wealth of technology but the Japanese are more effective at taking the technology and applying it into commercially viable products.

- We must realize that in the commercial market, you can not transfer technology, you can only transfer solutions to problems/needs which are application sensitive.

- Most of the Government Agency's charters are not designed to develop products/solutions compatible with commercial products/needs and do not have technology transfer as a high or primary priority.

Steven E. Scarborough (cont'd):

- There is no organization like MITI in Japan, or like ESPRIT in Europe, formed to work with industry and to transfer the technology needed to be commercially competitive.

- I recommend establishing an organization that has the charter of working with industry to develop and transfer appropriate technology for the commercial marketplace.

- The Government, industry and the educational institutions all have to work together as a team to effectively implement and carry out an effective solution.

Steve Babcock:

- Is the right technology being developed in the labs?

- Is the technology being developed ready to be transferred?

- Is industry ready to accept the technology?

- It takes time to really get an idea from the labs into production.

- We need to place more emphasis on process development.

- A complete understanding of a process is needed to fully use new technology.

- "Networking" between the labs and industry is needed for success.

- Lab personnel need to work with industry teams on the factory floor for successful technology transfer.

Dick S. Lopatka:

- IPE is very important to industry, particularly via integrated systems with robotics, controls and sensors.

- IPE R&D is part of a larger national problem of poor teamwork in industrial R&D.

- IPE R&D in USA not at critical mass in order to compete worldwide.

- As currently structured, national labs and agencies not able to deliver to industry at needed levels.

- Primary lab and agency missions do not allow individual labs and agencies to scale up to needed efforts.

- Issues of providing IPE R&D within time, cost and capability need to be addressed.

- Recommendation: Establish a lead agency for coordinating a national, coordinated effort for each critical technology.

Robert Becker:

- Return the investment tax credit (I.T.C.) of 10% (or 15%) for capital produced within the U.S. (50%), thus stimulating recapitalization and infrastructure improvements.

- Creating an educational tax credit (E.T.C.) to help retrain our workforce with many changing technologies and cooperative management styles including total quality/process improvement.

- Create a single source database of complete information of research and federally funded projects.

Michael Cronin:

- Continue to fund basic research, especially in new fields.

- Spend more effort in grouping the R&D reports under industrial market categories (e.g., robots, biotech, transportation).

- Report at the national trade shows such as Autofact, which are attended by many engineers and executives.

- Continue SBIR and other programs while monitoring their use as an enhancer or accelerator of commercial technology not an end to themselves.

- Consider espousing a few national industrial goals (not policies) such as:

    - Electric Cars
    - Aids Cure
    - High Definition TV

- Use defense funds to improve the teaching of current technology tools at universities (such as by providing CAD terminals).

- Appoint lead agencies or consortia to fund, organize and communicate developments in new technologies (such as Wright Patterson AFB to manage composite material technology).

Charles Hamermesh:

- Successful technology transfer depends on talking at the right place, to the right people, and offering the right answer.

- The audience being addressed in new technology has little knowledge of the new technology and must be educated.

- Market research is essential in locating the proper audience (i.e., market) for this transfer. Small businesses may be more assessable to this than very large companies.

- Government participation should involve funding programs to educate companies on the potential for the technology in their business niche and in the market research survey to identify these niches where the technology can be of use.

SECTION I:

Agency IPE Papers and Appendices:

- USDA
- DOE
- DOC
- DOD/Air Force
- DOD/Army
- DOD/Navy
- DOD/DLA
- DOD/SDIO
- DOD/MTIAC
- EPA
- FEMA
- NASA
- NIH
- NSF

SECTION I

ADVANCED MANUFACTURING AND VALUE-ADDED PRODUCTS FROM U.S. AGRICULTURE

Dr. Ruxton H. Villet
National Program Leader
Product Utilization
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Beltsville, Maryland 20705

Dr. Dennis R. Child
National Program Leader
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Manufacturing new and improved products from agricultural commodities is a key goal of the USDA. In fact, the seal of the USDA, originally founded in the 19th century, proclaims "Agriculture is the foundation of manufacture and commerce." Opportunities for transforming the rich, renewable resource of U.S. agriculture into value-added processed products are many. The food industry itself is one of the largest U.S. manufacturing industries.

Not only food products but also nonfood industrial products provide a considerable market potential. Such nonfood industrial products from agriculture could replace products that are at present manufactured chiefly from petroleum based materials. There is strategic advantage in having a renewable resource for the base material. Moreover, bioprocessing is an avenue to the type of environmentally benign products sought after in the present drive toward "green consumerism."

An objective of the USDA Agricultural Research Service (ARS) is to develop technology leading to a broad portfolio of value-added marketable products. Modern scientific disciplines such as chemical engineering are brought into play to develop processes for converting bulk commodities such as cereal starches, vegetable oils and dairy materials into high-margin products. To accomplish this, the extremely sophisticated processing devices which form the basis of modern biotechnology, namely, genes and enzymes, can be tailored to perform the required functions.

Environmentally attractive products can be made by exploiting the polymeric nature of cereal starch. Biodegradable plastic materials such as films for agricultural mulching and for trash can liners will reduce landfill loadings. Starch encapsulation of chemical pesticides permits lower application rates and diminished groundwater pollution.

The market for pesticides exceeds $16 billion. Chemical pesticides can be injurious to the environment and to human health, if they are misused. Re-registration of pesticides is becoming less and less attractive to industrialists. Substitutes must be found. Biological control agents synthesized by microorganisms and plants offer opportunities. ARS is developing bioprocess systems for manufacturing biopesticides from cornstarch.

Success has been achieved in making biodegradable inks from soybean oil. This vegetable oil could eventually displace petroleum as a vehicle in newsprint ink and lead to increased utilization of soybean to the extent of 100 million bushels. Environmental advantages include the elimination of petroleum based solvents from the work-place and also, since soy-ink is biodegradable, reduced landfill burden.

Arising from health concerns, consumers are crying out for natural products. ARS has research projects focussed on natural colors for the food and cosmetics industry and on a range of flavors, preservatives and textures as natural food additives. Microorganisms are tailored to convert dairy lactose waste to these desirable products. A fat substitute known as Oatrim was developed recently by treatment of oat bran with enzymes. This has the mouthfeel of fat but contains none.

U.S. imports of natural rubber amount to almost a billion dollars per year and there is strategic motivation for developing domestic substitutes. In long-range research ARS is developing a bioreactor system which will permit the manufacture of rubber latex from starch.

These are but a few examples. To accelerate the flow of technology from the initial research ideas to marketable products, ARS is exploiting patent/licensing mechanisms to the full. The Federal Technology Transfer Act permits exclusive rights to be given to industrial partners. ARS has in place more than 200 Cooperative Research and Development Agreements. During 1991 more than 25 licenses have been taken up by industry nd several new business enterprises have been set up based on technology created by ARS.

Along with advanced manufacturing systems which focus on bioprocess development, ARS has a range of projects related directly to intelligent processing equipment (IPE). On the pre-harvest side IPE technology will lead to improved efficiencies of crop production. Post-harvest equipment will permit the development of products with novel characteristics that appeal to consumers. Some salient examples will now be discussed.

Combining expert systems with simulation models has provided an excellent base for intelligent processing equipment. Two examples of USDA/ARS developed technologies are NUMEX and GOSSYM/COMAX. The Nutrient Management Expert System (NUMEX) was developed for Soil Testing Laboratories. The combined expert system and lab information system accumulates data on the residual fertilizer content of field soil. It then recommends the amounts of manure, sewage sludge, and commercial fertilizer that should be applied to grow the crops without contaminating surface water or ground water. The GOSSYM/COMAX decision aid was developed for cotton farmers. It uses weather, soil, and management data for the cotton fields to predict the need for irrigation, nitrogen fertilization and growth retardants, and to advise the timing of application of harvest aid chemicals. The expert system portion (COMAX) can also be used to facilitate the use of models for other agricultural crops.

Several technologies have been developed to improve grading and quality of meat processing. An automated machine that excises undesirable material from meat has been developed by USDA/ARS. The device is used to optically detect and locate undesirable material in meat and excise the undesirable material by various means. Another knowledge based system has been developed for grading meat. On the basis of answers to questions about the carcass, the expert system will evaluate yield and meat quality. Still another expert system characterizes marbling in beef ribeyes and its relationship to taste. The system simulates the visual capabilities of a trained meat grader. The system can be used to correlate visual cues to meat quality: tenderness, flavor intensity, and juiciness.

Intelligent processing equipment has been developed to simulate and control glucose concentration in hot water blanching of potatoes. The concentration of glucose in a hot water blancher is monitored continuously and the results are used by a computer simulation model to adjust water temperature, water volume and/or extraction time in order to minimize browning. Another food processing simulator model has been developed that can mimic the effects of various processing procedures. Using this tool, food processors can evaluate their current systems and use information from the food processing simulator to improve quality, reduce waste, and optimize energy use.

Intelligent processing equipment, developed by USDA/ARS, is used to increase efficiency of fermentation by controlling the feed rate to a culture using a heat-flux sensor. The loss of volumetric productivity in fermentations that are subject to substrate inhibition can be overcome by feeding substrate at a rate which coincides with the microbe's instantaneously measured requirement for substrate.

Computerized gin process control technology, developed by USDA/ARS, has markedly improved the efficiency of cotton ginning. Electronic devices are used to measure moisture, color, and foreign matter in cotton in order to control the gin process. The dynamic computer model selects which of a number of seed cleaners, driers, and lint cleaners is most appropriate for the cotton being ginned.

Intelligent processing equipment to reduce power consumption by irrigation pumps has been developed by USDA/ARS. The system calculates how much pressure is required from pumps to move water to center pivot sprinklers. The computer monitors and adjusts the individual performance characteristics of each pump in the system and keeps track of the peak electrical demand of each pump station.

A robotic system has been developed by USDA/ARS to automate atrazine and alachlor extraction from soil. The robotic method for the extraction of herbicides from soil reduces labor, improves extraction efficiency and precision, and increases sample throughput by a factor of three.

Many of the intelligent processing equipment applications used in agriculture require new automated monitoring procedures and sensors. New sensors have been developed by USDA/ARS to aid in a number of intelligent processing applications. A brief summary of some of these new technologies follows:

> Insect detection using a pitfall trap having vibration detection. A pitfall probe trap is used to detect the presence or absence of live insects and estimate insect numbers.
>
> Estimation of fumigant residues in commodities. The concentration of residual fumigant in a commodity in a fumigation chamber is estimated from the rate of decline in concentration of fumigant in the exhaust air stream during the aeration period following fumigation.
>
> Device for automatic extracting, grading and returning lint to gin system. Cotton lint is separated from a fluid-entrained stream, formed into a batt, and pressed by a weight against an analyzer in the duct wall. After analysis, the weight is removed to permit the batt to be replaced.
>
> Analysis of soil organic matter. A space-borne high spectral resolution imaging sensor can be used to measure soil organic carbon content.
>
> Ultrasonic tree caliper. An ultrasonic transducer is used to detect changes in tree trunk diameter as small as 0.25 cm.
>
> A biological sensor for available iron in the rhizosphere. This biological sensor is useful for assessing iron available to bacteria in culture and on plant surfaces. A novel biological sensor for available iron was constructed by cloning an iron-regulated promoter from a pyoverdine biosynthesis gene upstream of a promoterless ice nucleation gene.
>
> An electronic "apple" records impacts in packing houses. An electronic sphere records the duration, time, and magnitude of impacts to fruit during the packing process. The commercially available sphere is currently being used throughout the world to reduce bruising on an array of fruits and vegetables, including tomatoes, peppers, beets, and potatoes.
>
> Analysis of radiograms of wheat kernels for quality control.
>
> Real time X-ray inspection for agricultural contraband has been tested during unloading of checked airline bags on international flights. All X-ray images were digitized and stored on disk.

Image enhancement outlined shapes of rounded food items such as fruits.

Detection of submilligram inclusions of heavy metals in processed foods. X-ray radiography and scanning electron microscopy are used to identify particulate contaminants in frozen TV dinners.

Mapping field soil salinity while cultivating. Tractor mounted sensors use either soil conductivity or electromagnetic induction to measure soil salinity. The position of the tractor is determined by a satellite-linked global tracking system and accurate, detailed maps of field soil salinity are produced.

Equipment for testing the hardness of wheat. Hard wheat is used to make bread, soft wheat to make cakes. The hardness of wheat is assessed in equipment that measures: the forces needed to crush the kernel; kernel size; kernel weight; conductivity and moisture content.

USDA/ARS is a leader in the development of intelligent processing equipment for agriculture in the broadest sense. Applications of IPE are found in the production, processing, grading, and marketing aspects of agriculture. Appropriate technologies in agriculture can insure a brighter future for the people of the United States as we move into the next century and maintain our strong competitive position in the global economy.

U.S. DEPARTMENT OF AGRICULTURE (USDA)
IPE RELATED PROJECTS

CATEGORY: CONTROLS

NUMEX: A Nutrient Management Expert System for Soil Testing Laboratories
USDA/ARS, Hal E. Lemmon, SRL, 510-559-5965
A combined expert system and lab information system accumulates data on the residual fertilizer content of field soil. It then recommends the amounts of manure, sewage sludge, and commercial fertilizer that should be applied to grow the crops without contaminating surface water for ground water.

GOSSYM/COMAX: a decision aid for cotton farmers
USDA/ARS, James M. McKinion, CSRU, 601-324-4375
A combined expert system and crop simulation model uses weather, soil, and management data for the cotton fields to predict the need for irrigation, nitrogen fertilization and growth retardants, and to advise the timing of application of harvest aid chemicals

Automated Excision of Undesirable Material from Meat
USDA/ARS, W. Heiland, R. Konstance, ESRU, 215-233-6590
The device is used to optically detect and locate undesirable material in meat and excise the undesirable material by various means.

Simulation and Control of Glucose Concentration in Hot Water Blanching of Potato
USDA/ARS, Peggy M. Tomasula, ESRU, 215-233-6648
The concentration of glucose in a hot water blancher is monitored continuously and the results are used by a computer simulation model to adjust water temperature, water volume and/or extraction time in order to minimize browning

Self Tuning Controller for Farm tractor Guidance
USDA/ARS, Donald C. Erbach, NSTL, 515-294-5725
An electronic system has been developed that can steer a tractor under field conditions. The computer system is self-tuning and makes use of a "variable-forgetting-factor" method to correct for driving errors that can occur when planting, cultivating, and harvesting.

Computer Simulation of Potato Processing
USDA/ARS, Michael F. Kozempel, ESRU, 215-233-6589
A food processing simulator model has been developed that can mimic the effects of various processing procedures. Using this tool, food processors can evaluate their current systems and use information from the food processing simulator to improve quality, reduce waste, and optimize energy use.

Control of Feed Rate To a Fed-Batch Culture Using a Heat-Flux Sensor
USDA/ARS, Robert W. Silman, FBRL, 309-685-4011
The loss of volumetric productivity in fermentations that are subject to substrate inhibition can be overcome by feeding substrate at a rate which coincides with the microbe's instantaneously measured requirement for substrate.

Computerized Gin Process Control
USDA/ARS, William S. Anthony, CGRL, 601-686-2385
Electronic devices are used to measure moisture, color, and foreign matter in cotton in order to control the gin process. The dynamic computer model selects which of a number of seed cleaners, drivers, and lint cleaners is most appropriate for the cotton being ginned.

A Computer Program to Cut Power consumption by Irrigation Pumps
USDA/ARS, Dale Heerman, Gerald Buchleiter, IDRL, 303-491-8229
the program calculates how much pressure is required from pumps to move water to center pivot sprinklers that the irrigator needs. The computer knows the individual performance characteristics of each pump in the system and keeps track of the peak electrical demand of each pump station.

CATEGORY: SENSORS

Insect Detection Using a Pitfall Trap Having Vibration Detection
USDA/ARS, Kenneth W. Vick, BERRL, 902-374-5772
A pitfall probe trap is used to detect the presence or absence of live insects and estimate insect numbers

Estimation of Fumigant Residues in Commodities
USDA/ARS, Charles R. Sell, Mark A. Weiss, FVIRL, 509-575-5967
The concentration of residual fumigant in a commodity in a fumigation chamber is estimated from the rate of decline in concentration of fumigant in the exhaust air stream during the aeration period following fumigation.

Device for Automatic Extracting, Grading and returning Lint to Gin System
USDA/ARS, William S. Anthony, CGRL, 601-686-2385
Cotton lint is separated from the fluid-entrained stream, formed into a batt, and pressed by a weight against an analyzer in the duct wall. After analysis, the weight is removed to permit the batt to be replaced.

Analysis of Soil Organic Matter
USDA/ARS, Diane E. Stott, NSERL, 317-494-6657
A spaceborne high spectral resolution imaging sensor can be used to measure soil organic carbon content.

Application of Knowledge Based System for Grading Meat
USDA/ARS, Yed-Ren Chen, Steven A. Robinson, BERL, 402-762-4271
This expert system is designed to assist in grading meat. On the basis of answers to questions about the carcass, the expert system will evaluate yield and meat quality.

Characterization of Marbling in Beef Ribeyes and Its Relationship to Taste
USDA/ARS, Timothy McDonald, BERL, 402-762-4273
A system has been developed which simulates the visual capabilities of a trained meat grader. The system can be used to correlate visual cues to meat quality: tenderness, flavor intensity, and juiciness.

Ultrasonic Tree Caliper
USDA/ARS, Bruce L. Upchurch, AFRL, 304-725-3451
An ultrasonic transducer is used to detect changes in tree trunk diameter as small as 0.25 cm.

A Biological Sensor for Available Iron in the Rhizosphere
USDA/ARS, Joyce Loper, HCRL, 503-757-4544
This biological sensor is useful for assessing iron available to bacteria in culture and on plant surfaces. A novel biological sensor for available iron was constructed by cloning an iron-regulated promoter form a pyoverdine biosynthesis gene upstream of a promoterless ice nucleation gene.

Instrumented "Apple" Records Impacts in Packing Houses
USDA/ARS, Galen Brown, FVHRL, 517-353-5185
An electronic sphere records the duration, time and magnitude of impacts to fruit during the packing process. The commercially available sphere is currently being used throughout the world to reduce bruising on an array of fruits and vegetables, including tomatoes, peppers, beets, and potatoes.

Analysis of Radiograms of Wheat Kernels for Quality Control
USDA/ARS, T.F. Schatzki, T.A. (Bryant) Fine, FQRL, 510-599-5672
X-ray pictures of wheat kernels can be used to detect the presence of hidden insect pests in stored grains between one and four weeks after the eggs were laid.

X-Ray Imaging of Baggage for Agricultural Contraband
USDA/ARS, Thomas F. Schatzki, Richard Young, FQRL, 510-559-5672
Real time X-ray inspection for agricultural contraband has been tested during unloading of checked airline bags on international flights. All X-ray images were digitized and stored on disk. Image enhancement outlined shapes of rounded food items, such as fruits.

Detection of Submilligram Inclusions of Heavy Metals in Processed Foods
USDA/ARS, T.F. Schatzki, R.Y. Wong, FQRL, 510-559-5672
X-ray radiography and scanning electron microscopy are used to identify particulate contaminants in frozen TV dinners.

Mapping Field Soil Salinity While Cultivating
USDA/ARS, Jim Rhoades, USSL, 714-369-4815
Tractor mounted sensors use either soil conductivity or electromagnetic induction to measure soil salinity. The position of the tract is determined by a satellite-linked global tacking system and accurate, detailed maps of field soil salinity are produced.

Equipment for Testing the Hardness of Wheat
USDA/ARS, James Steele, Charles R. Martin, ERL 913-776-2727
Hard Wheat is used to make bread, soft wheat to make cakes. The hardness of wheat is assessed in equipment that measures: the forces need to crush the kernel; kernel size; kernel weight; conductivity and moisture content.

CATEGORY: ROBOTICS

Automation of Atrazine and Alachor Extraction from Soil Using a Robotic System
USDA/ARS, William C. Koskinen, SWMRL, 612-625-4276
A robotic method for the extraction of herbicides from soil has been found to reduce labor, improve extraction efficiency and precision, and increase sample throughput by a factor of three.

INTELLIGENT PROCESSING EQUIPMENT RESEARCH AND DEVELOPMENT PROGRAMS OF THE DEPARTMENT OF COMMERCE

J.A. Simpson
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National Institute for Standards and Technology
Department of Commerce

The Intelligent Processing Equipment (IPE) research and development programs of the Department of Commerce are carried out within the National Institute of Standards and Technology (NIST). This Institute, formerly the National Bureau of Standards, has had work in support of industrial productivity as part of its mission since its founding in 1901. With the advent of factory automation these efforts have increasingly turned to research and development in IPE. The Manufacturing Engineering Laboratory (MEL) of NIST devotes a major fraction of its efforts to this end while other elements within the organization, notably the Material Science and Engineering Laboratory, have smaller but significant programs. Appendix A is an inventory of all such programs at NIST. In the time allotted it is impossible to discuss all or most of the projects, so this presentation will restrict itself to a representative selection of projects that at least demonstrates the scope of the efforts.

All the efforts make extensive use of Cooperative Research and Development Agreements (CRADA) to work with the private sector on collaborative programs. At NIST there are currently 111 such agreements in force and an additional 58 in the process of being finalized. Of these, 21 are in place in MEL with 12 more pending.

One of the largest of these cooperative endeavors is the Automated Manufacturing Research Program within the NIST Manufacturing Engineering Laboratory. This program, when started a decade ago, centered around the construction of an Automated Manufacturing Research Facility (AMRF) to provide a testbed for intelligent processing systems for metalworking.

The initial focus was the development of a control architecture, hierarchical in nature and based on the artificial intelligence concepts of finite state machines, which could be used across all levels of a system using IPE. This highly modular architecture provided uniform interfaces for the sensors and for the command and sensory chains between the various IPE within the system. The lowest level of this hierarchy, the NIST Real Time Control System (RCS) architecture has found wide application for control for space telerobotics and for terrestrial robotics for mining and autonomous vehicles. In fact it has been adopted by NASA as the NASA Standard Reference Model (NASREM).

The AMRF was a highly cooperative venture with the US Navy Manufacturing Technology Program (Man-Tech) as a full partner and with the Companies shown on Figure 1 providing material support. The program resulted in the development of a number of patents as shown in Figure 2, and the commercialization of several devices as shown in Figure 3.

Drill-up (see Figure 4) is a particularly interesting example of IPE. The problem addressed was breakage of 1 millimeter twist drills during the fabrication of perforating dies for the production of postage stamps. The fabrication of these dies required the drilling of several thousand small holes in a pattern corresponding to the shape of the individual stamps in the sheet. Earlier work on the machining center had shown that with software correction of machine errors the tight tolerances required could be met on conventional machines, but drill dulling and subsequent drill breakage was occurring every few hundred holes even with frequent drill replacement.

Drill-up was a micro-processor based acoustic signature device which "listened" to the sound of drilling and could reliably detect the dulling of the drill and order an automatic drill change before breakage could occur. After installation of the device over half a million holes were drilled without breakage, and drill life was more than doubled.

Work of a similar nature continues in a project called Quality in Automation (QIA) (See Figure 5). What is involved here is to make the processing equipment more intelligent by increasing its "self consciousness." By the use of sensors and on-line probing of the part during processing the machines are aware of their thermal state, their in-built static errors and their demonstrated performance measured against set goals. This information is utilized by a real-time software based error correction system to close the gap between desired performance and actual behavior. It has been shown that even relatively simple correction software can improve the accuracy of both machining centers and lathes by factors of 5 to 20.

Besides improved unit processing equipment entire subsystems of the AMRFwere also successfully transferred into industrial settings. These subsystems are listed in Figure 6. In addition two work stations, one for pipe fittings the other for precision threaded fasteners, were developed at NIST and transferred to Navy shipyards.

Further work on intelligent mechanical processing equipment is currently in hand. Notable among the projects is the Advanced Deburring and Chamfering System (ADACS), (see Figure 7). In this effort engineers are developing an automated system which produces precision chamfers on aircraft engine components fabricated from titanium and inconel. The chamfers, or beveled edges, must be placed on parts such as turbine engine blades and hubs to relieve potential areas of stress concentration and ease assembly. Because of the high machining value present in these parts by the time they reach the chamfering stage, damage to the part at this time can be very expensive. In order to reduce the scrap rate, engine manufacturers are highly motivated to automate the process. The system is being developed in a cooperative effort between NIST and United Technologies Research Center (UTRC), and includes engine manufacturer Pratt and Whitney. To date UTRC has completed work on process models which dictate the cutting force required to achieve a desired chamfer depth. The next phase of the project at NIST will combine UTRC's process expertise and NIST's experience in automation.

The ADACS builds on work performed in the Automated Manufacturing Research Facility over the past five years. Techniques were developed in a Cleaning and Deburring Workstation for generating robot trajectories off-line, using computer-aided design data. The NIST Real-time Control System (RCS) allows feedback from a variety of sensors to be easily integrated with the control of the robot, accommodating for robot inaccuracy which may result from off-line programming. Such techniques enable automatic generation of reliable robot programs in a matter of seconds or minutes, instead of the hours or days required for manual teaching.

The ADACS consists of a six-axis electric robot fitted with an actuated chamfering tool. This tool is capable of high speed force control within a small work area. The approach is to use the conventional industrial robot as a coarse positioning device, while relying on the actuators and force sensors of the tool to provide control over cutting force and tool stiffness at the part edges. The tool also compensates for robot inaccuracies and other factors such as part misalignment and large tolerances. The system has maintained chamfers of 0.4 mm (15 thousands of an inch) on titanium while traversing corners, in spite of part positioning errors on the order of several millimeters.

The NIST work on IPE has recently expanded to include processes other than metalworking. In cooperation with the Material Science and Engineering Laboratory (MSEL) MEL has initiated work on intelligent control of Metal Atomization and Thermoplastic lay-up of composites.

The first of these, Metal Atomization (See Figure 8), has focused on providing the ability to monitor and control particle size during atomization. Several important properties of metal powder and their consolidated products have been shown to depend on the as-atomized particle size. These properties include mechanical performance (e.g., strength, toughness, creep resistance) as well as physical characteristics of the powder itself (e.g., particle shape, porosity, flow qualities). This strong dependence of properties on particle size translates into an increased demand on the process engineer to control powder size dynamically during the atomization process.

Preparatory studies have been performed within MSEL, including gas and liquid flow imaging, gas flow modeling, real-time particle size measurement, and process control.

The process controller incorporates a multilevel expert system shell and a novel realtime particle size distribution measurement sensor. This sensor incorporates an adaptive pattern recognition scheme which makes use of the concept of neural-net computation capable of "learning" behavior. The nonintrusive line-of-sight laser diffraction particle-sizing apparatus has been successfully tested during several metal powder atomization runs. Particle size distribution data were computed from scattered-light data using the pattern recognition scheme at rates exceeding 20 Hz. The expert system process control is based on the AMRF hierarchical control architecture and has been developed featuring a generic structure that allows easy adaption to processes other than the currently configured inert gas metal atomizer.

In another, very different, IPE effort of MEL and MSEL, the engineering staff of the Automated Manufacturing Research Facility have been developing a workstation to conduct research into the manufacture of components from advanced thermoplastic composites using robotic fiber placement (See Figure 9).

The long term goals of this workstation are to develop the ability to manufacture complex shaped components and to demonstrate product improvements by incorporating sensor feedback into a real-time hierarchal control system. Much of the potential benefits of using thermoplastics in composite structures lies in the thermoplastic's ability to be consolidated during the initial lay-up (in-situ consolidation), thus avoiding autoclave curing requirements. In-situ consolidation occurs when melted thermoplastic composite material is added under pressure to a substrate which is likewise locally melted. Under proper conditions, the thermoplastic flows between the existing substrate and the new material then solidifies into a strong bond.

At the inception of the Composite Workstation, a viable in-situ process for consolidation was not available. The focus of work has, therefore, so far been on refining a process for the in-situ consolidation of Carbon/PEEK (APC2/AS4) thermoplastic prepreg. The process uses air heaters to bring the thermoplastic up to a processing temperature (400°C) and a steel wheel and band to provide compaction pressure. This compaction device generates a high pinch pressure at initial contact, followed by a sustained lower pressure provided by the band. The resulting total compaction time is several orders of magnitude greater thenwith most processes which use only a circular compaction wheel.

During the period of process refinement, the workstation has produced standard test rings of 14.6 cm(5 3/4 inch) diameter, 0.31 mm (1/8) inch thick ring for several standard tests. These test samples show between 99.1% and 96% void-free consolidation in the center plies when laid up at between 12 and 50 millimeters per second. The workstation is continuing efforts to improve consistency, to improve initial and outer ply consolidation, to resolve sticking problems, and to further modify the process for use on concave surfaces. Future work will focus on the development of the robotic manipulators for manufacturing complex shapes and on the control system for these devices using real-time sensory feedback from various position, force and temperature sensors.

These projects are typical of the many others in the Department of Commerce/NIST program in Intelligent Processing Equipment. With our Navy and Industrial partners, NIST will continue to seek out new fields where the unique mission of the Institute, to support U.S. productivity enhancement, can be fulfilled by utilizing the skills of NIST laboratories in measurement, sensors, and intelligent machines. Besides the work described on the equipment itself we are engaged in a major effort to improve mans ability to communicate his desires to IPE and to those who operate such equipment. This work involves the development of higher level languages for machine control and the interface between Computer Aided Design (CAD) and the Computer Aided Manufacturing Systems (CAM) which embody IPE. Central to this goal is collaboration with a wide community of Government and private sector interests in developing a 21st Century replacement for the mechanical drawing.

Mechanical drawings are fundamentally "wire frame" models showing only edges. While men can interpret these models with little difficulty, intelligent machines cannot, nor are they likely ever to be able to do so since essential information about the described part is only there implicitly. This effort called PDES, which is a nested acronym standing for Product Data Exchange Using STEP, where STEP is Standard for Exchange of Product Model Data (an International Standards Organization (ISO) term). This work, although only supportive of IPE, is vital to its impact on productivity.

I would like to extend to each of you and your organizations an invitation to come visit MEI~NIST at Gaithersburg MD., just out-side Washington D.C., see what we are doing and explore the possibility of joint efforts under Cooperative Research and Development Agreements.

DEPARTMENT OF COMMERCE
SURVEY OF IPE RELATED PROJECTS AT NIST

TITLE: Active Vibration Isolation System for the Molecular Measuring Machine
ORGANIZATION/CONTACT: NIST/MEL/PED; Dennis Swyt
PROJECT SUMMARY: This project supports the development by NIST of an ultra-high precision coordinate measuring machine (CMM) called the Molecular Measuring Machine (M^3) This machine is intended to measure to atomic scale accuracies over an area of 2500 sq. mm and provide measurement services for the high density circuits developed by the U.S. semiconductor industry and ultra-smooth optical surfaces for the defense industry. The technical activities include cooperative development and simulation of a multidegree of freedom adaptive vibration isolation algorithm to control the M^3 core metrology structure vibration isolation and the implementation of the algorithm to a test facility model to determine the frequency bandwidth of its control capability. The control actuators, sensors and algorithm would then be transferred to the M^3 system.
CATEGORY: Controls

TITLE: Coordinate-Measuring-Machines in Automated Inspection Systems
ORGANIZATION/CONTACT: NIST/MEL/PED; Dennis Swyt
PROJECT SUMMARY: This project supports development by U.S. industry of high-performance coordinate-measuring-machines (CMMs) for the flexibly-automated inspection of manufactured parts including, for example, aircraft turbine engine components and automobile power train elements. The technical activity includes cooperative development and testing of measurement-specific data-representation standards and techniques for evaluating the measurement accuracy of commercial CMMs under temperature variations of the machine and workpiece.
CATEGORY: Sensors (Measurement Systems)

TITLE: Feasibility of In-Process Monitoring for Process Control
ORGANIZATION/CONTACT: Automated Production Technology Division; Donald Eitzen
PROJECT SUMMARY: This project establishes the feasibility of applying sensing technology to various, specific manufacturing process control problems. The objective of the project is to transfer NIST sensor technology expertise to industrial manufacturers with process monitoring problems they have identified. Typically the manufacturer provides expertise on the process and characterized product samples and NIST determines an appropriate sensing and control strategy. As part of this project feasibility is being determined for in process on line monitoring of:

- thickness of convoluted plastic conduit with Packard Electric/GM,
- surface finish and subsurface damage of ceramics and glass optics with Danbury Optical Systems,
- pitch, depth, and area ratio of heat exchanger waffling for the M-l tank with Manufacturing Resources, Inc. (MRI),
- detection of laminar carbon in Cu-Be stock for Ford electrical connectors with MRI.

CATEGORY: Controls

TITLE: Ultrasonic Surface Finish Monitor for Navy Jet Engines
ORGANIZATION/CONTACT: Automated Production Technology Division; Donald Eitzen
PROJECT SUMMARY: The objective of this project is to provide the technology and expertise to enable a major navy jet engine supplier to monitor in-process the surface finish of jet engine shafts and discs. This will result in improved quality and improved process efficiency by achieving appropriate surface finish and by providing a tool management strategy. The major research activities at NIST will be to determine the basic measurement parameters and an optimum measurement protocol for this specific application. The measurement parameters include transducer design (element size, frequency, focus condition) excitation, and first stage signal processing which must be determined for the range of geometries, materials and surface finishes to be measured. One industrial partner, Apeiron, will concentrate on software for additional signal processing, display and control and on measurement system packaging. General Electric, Aircraft Engines Group will provide a demonstration platform to demonstrate and exercise the system.
CATEGORY: Sensors, Controls

TITLE: Ultrasonic Determination of Part Seating
ORGANIZATION/CONTACT: Automated Production Technology Division; Donald Eitzen
PROJECT SUMMARY: A national laboratory is developing a precision CNC machining system for unattended manufacturing of hemispherical shells. During final machining the part is held in a vacuum chuck and the proper seating of the part is critical to the part accuracy. This project is developing an automated measurement system for determining the quality of part seating by scanning and measuring the part/chuck interface impedance. The vacuum groves in the chuck provide a convenient calibration/contrast agent. The determination is made between process after a part has been automatically transferred from a chuck for external machining to the vacuum chuck for internal machining.
CATEGORY: Sensors, Controls

TITLE: Ultrasonic Part Thickness Monitor
ORGANIZATION/CONTACT: Automated Production Technology Division/Donald Eitzen
PROJECT SUMMARY: The project is developing an automatic part thickness measurement system for a group of CNC machine tools operated for the U.S. government. The parts are thin metal shells which are mounted in a vacuum chuck. The part thickness measurements are made noncontact, in situ, and with access to only one side of the part. The extant cutting fluid/coolant is used to couple the ultrasound into the part. Thickness measurements are made before the final cut at about 60,000 locations in a matter of minutes to an accuracy of better than 0.0001 in. The system provides a detailed map of actual thickness so that the final cut can be modified to produce a good part. It is anticipated that as dimensions are compared between the ultrasonic system and the tedious method currently used for acceptance testing, over time the ultrasonic system will be used for final acceptance. It is a PC controlled system which is interfaced with an ultrasonic measurement system and a CNC machine tool.
CATEGORY: Sensors, Controls

TITLE: Statistical Process Control of Small-lot Production
ORGANIZATION/CONTACT: Automated Production Technology Division; Kang Lee
PROJECT SUMMARY: In small-lot flexible production systems, parts are produced and post-process gaged to determine whether the parts meet required specifications. Using this approach, parts are frequently scraped due to tool wear, thus valuable production time and expensive material are wasted. The goal of the project is to use sensor-feedback data and apply statistical process control (SPC) methods to close the measurement and control loop in the manufacturing process. By analyzing the sensor-feedback data, control algorithms can be developed to optimize part-gaging frequency and to compensate for part dimensional variations caused by tool wear. Applying SPC techniques in sensor-based control systems, the quality of parts produced should be improved and the manufacturing efficiency increased.
CATEGORY: Sensors, Controls

TITLE: Portsmouth Fastener Workstation
ORGANIZATION/CONTACT: Automated Production Technology Division; Kang Lee
PROJECT SUMMARY: The Portsmouth Fastener Workstation is a joint research and development project conducted by the Automated Production Technology Division of the Manufacturing Engineering Laboratory and the Portsmouth Naval Shipyard, with the collaboration of industry partners. The goal of the project is to transfer the technology that we pioneered at the AMRF, such as error correction, hierarchical control, and data-driven system approach, to other government agencies and the private sector. In this project we will develop the necessary technology, methodology, state-machine based controller, and computer control systems for the efficient production of high-quality,level-l,k-monel fasteners that meet government and industry standards.
CATEGORY: Sensors, Controls

TITLE: Machining Cell Emulation System
ORGANIZATION/CONTACT: Factory Automation Systems Division; PMSG Mark E. Luce, X2802
PROJECT SUMMARY: The Machining Cell Emulation Project is Developing a Multi-Platform Emulation System for Manufacturing cells. This system is designed to mimic the behavior of an actual cell, i.e., respond to command, execute process plans, consume resources, generate data, breakdown. And exhibit non-deterministic behavior. The existing system serves two purposes: 1. to examine alternative tool management strategies for machining cells and 2. to test and verify the Manufacturing Systems Integration Architecture.
CATEGORY: Controls

TITLE: Manufacturing Systems Integration
ORGANIZATION/CONTACT: Factory Automation Systems Division; PMSG Mark E. Luce, x2802
PROJECT SUMMARY: The MSI Project is developing a system Architecture that Incorporates an Integrated Production Planning and control Environment. A major activity of the MSI project is the cyclic Implementation, Testing and Refinement of an Architecture until a complete, detailed, implemented, and thereby proven, architecture is developed. Thus the MSI system will function as a testbed for Production Management Architectures Integrating Process Planning, Production Planning, and shop floor control. The verification of the MSI architecture will be via successful production of selected parts from multiple manufacturing domains, using either actual or emulated shop floor equipment or the combination of both.
CATEGORY: Controls

TITLE: Process Planning for ADACS
ORGANIZATION/CONTACT: Intelligent Controls Group, Robot Systems Division; Ron Lumia
PROJECT SUMMARY: Small batch manufacturing will never occur unless the time required to develop process plans becomes significantly shorter than the time required to execute the plans. This project employs the graphical programming techniques to develop robot process plans for the ADACS workstation. The programmer creates a simulation of the workstation executing his plans. Once satisfied with the result, the plans are sent to the real robot for execution. This provides a safe and efficient environment for the development of robot process plans.
CATEGORY: Robotics, Controls

TITLE: CALS PROGRAM SUPPORT
ORGANIZATION/CONTACT: OASD(P&R) CALS Evaluation & Integration Office; Dr. Marianne Pietras, 703-697-0051
PROJECT SUMMARY: Support the DOD CALS Program Office in selecting and developing standards and technology for the Computer-aided Acquisition and Logistic Support (CALS) program. CALS is a DOD level initiative to effectively manage throughout the services and DLA (and in conjunction with industry) the transition from paper intensive information management to digital. The target is all of the information involved in the life cycle of a major weapon system (or industry major product); this includes engineering, manufacturing, acquisition, training, and maintenance, as well as electronic data interchange for electronic commerce. A major manufacturing interface has been the support of IGES, PDES, EDIF, VHDL, and other product data standards, selection and application; this includes an ongoing consideration of the BCL standard for machine tool controllers.
CATEGORY: Controls

TITLE: New Generation Machine Tool Controllers
ORGANIZATION/CONTACT: Automated Production Technology Divison (APTD); Alkan Donmez
PROJECT SUMMARY: In order to carry out sophisticated adaptive machining algorithms, the next generation machine tool controllers should have adequate interfaces and analysis capability of sensory inputs from various sensors during machining. APTD of MEL is working with machine tool controller builders to develop a new generation of machine tool controller which has an open architecture and based on reliable off-the-shelf electronic components.
CATEGORY: Sensors, Controls

TITLE: Environmental Effects on Single-Point Diamond Turning
ORGANIZATION/CONTACT: Automated Production Technology Divison (APTD)/Alkan Donmez
PROJECT SUMMARY: In order to evaluate the effects of airborne noise on the high-precision, single-point diamond turning process, APTD in cooperation with PED of MEL has carried out an experimental study. This study revealed the dynamic coupling between the machine tool structure and the environmental noise and its detrimental effect on part surface quality. A broad band white noise generated in the laboratory environment and the resultant surface quality was monitored using interferometric measuring instruments.
CATEGORY: Sensors

TITLE: On-Line, Adaptive Quality Control Architecture for Discrete Part Manufacturing
ORGANIZATION/CONTACT: Automated Production Technology Divison; Alkan Donmez
PROJECT SUMMARY: This project is an effort to develop and implement a real-time, on-line quality control architecture which utilize adaptive machining algorithms based on deterministic manufacturing principles. The Automated Production Technology Division and the Precision Engineering Division of the Manufacturing Engineering Laboratory are cooperating with machine tool industry and several universities to develop feature-based part inspection and analysis algorithms to identify and compare for the machine tool and the cutting process related manufacturing errors to improve quality of the parts.
CATEGORY: Sensors

TITLE: Geometric and Thermal Error Correction of Machine Tools
ORGANIZATION/CONTACT: Automated Production Technology Division; Alkan Donmez
PROJECT SUMMARY: The purpose of the project is to develop methods to characterize machine tool geometric and thermally induced systematic errors, to develop kinematic models to predict the resultant error of the cutting tool position, and to compensate for these predicted errors. APTD of MEL is cooperating with industry and academia to commercialize the results of this study.
CATEGORY: Sensors, Controls

TITLE: Generic Real-time Error Compensation Technology for Machine Tools
ORGANIZATION/CONTACT: Automated Production Technology Division; Alkan Donmez
PROJECT SUMMARY: In order to implement novel error compensation algorithms into machine tools, APTD of MEL has been developing an electronic device to be inserted between the machine tool controller and its feedback devices. This device, called Real-Time Error Connector (RTEC), is used to modify the tool path without any intrusion into the machine tool controller. This device can be interfaced to any type of machine tool controller.
CATEGORY: Sensors, Controls

TITLE: Air Force Next Generation Controller
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is to assist the Air Force and its contractors in the development of the Next Generation Controller (NGC). NGC is designed to become a standard for commercial controllers for machining workstations, including machine tools, robots, and coordinate measuring machines. NIST tasks include developing standards for NGC task decomposition modules and levels, data structures for NGC world modeling modules, and a Neutral Manufacturing Language for communications between functional modules. This research is being coordinated with the IMI ARTICS research in an effort to define an open system architecture and standardized interfaces which will lead to the first pre-commercial version of an intelligent control system. This intelligent control system may be subsequently commercialized for use by industry, government, and universily users for a wide variety of applications.
CATEGORY: Controls

TITLE: Process Sensors for Intelligent Systems
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is the investigation of various sensing techniques required by intelligent machine systems. These include advanced vision and camera systems that have non-uniform resolution (foveal/peripheral) sensors, active scanning of the fovea over points of interest in the scene, and use of knowledge about, or active control of, camera position and illumination. This research involves the development of Kalman filter techniques for fusing visual, tactile, and kinesthetic information about the position and shape of surfaces and objects. It also involves the development of instrumentation and methods for stereo vergence, object tracking, and real-time image processing. A vanety of sensors are being developed to measure the performance of intelligent machine systems. These include a laser tracker system for measuring the free space kinematic and dynamic motion perforrnance of robot systems. In addinon, a vanely of simpler and less expensive systems such as stnng encoders, electromagnetic, and acoustic length and position measunng devices are also be studied.
CATEGORY: Robotics, Sensors, Controls

TITLE: Intelligent Machines Initiative - Next Generation Controller
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is the development of a standard reference model open-system architecture for intelligent machine systems that will support their specification, design, construction, procurement, and testing. This standard, termed an Architecture for Real-Time Intelligent Control Systems (ARTICS), will serve as the foundation for the development of the next generation of intelligent control systems. This research will produce a set of interface standards based on this reference model architecture that will speed commercial development by promoting competition and facilitating incremental implementation and upgrading of intelligent machine systems. Also involved in this research is the development of a methodology for designing and implementing such a control system.
CATEGORY: Controls

TITLE: Intelligent Machines Initiative - Platform
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: Research is focused on methods for slabilizing and controlling robots suspended by cables from overhead lifting mechanisms such as cranes. Such robots will be able to move freely and perform useful work throughout the entire volume serviced by the crane. For example, they will be able to perform inspection, spray painting, sand blasting, or welding operations on very large structures such as ships, airplanes, and buildings. They will be able to lift, transport, and precisely position heavy loads such as panels, beams, and other objects weighing up to several tons. They will also be able to perforn grinding, drilling, routing, and excavating tasks with great precision over very large areas. This research involves the investi~ation of the charactenstics and performance of the basic mechanical configuration and the development of sensors and control system to actively control such a device.
CATEGORY: Robotics, Controls

TITLE: Intelligent Machines Initiative - Sensory Processing/World Modeling
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The basic research in sensory processing and world modeling is focused on the sense of vision, with particular emphasis on the use of vision for navigation, inspection, object and event recognition and tracking, as well as on the relationship between vision and manipulation. This basic research includes various aspects of rnachine vision, image processing, sensory data fusion, knowledge representation, decision theory, intelligent controls, and adaptive and learning systems. The goal of this research is to develop a formal theory of how intelligent machine systems can see, focus attention, and perceive the structure of the world well enough to accomplish a wide variety of tasks of inspection, manipulation, locomotion, and process control in complex and uncertain environments. Vision research will center on methods for estimating the position, orientation, shape, and texture of surfaces in space. Research on world modeling will develop data structures that can represent both spatial and symbolic infonnation about surfaces, objects, and regions of space.
CATEGORY: Robotics, Controls, Sensors

TITLE: DOD Unmanned Ground Vehicles - Robotics Testbed
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: This U.S. Army funded project is focused on the development of a high-level control system for unmanned land vehicles. This controller is based upon the NIST Real-time Control System (RCS), originally developed for the control of industrial robots in the AMRF. The RCS is used to control all vehicle mobility functions and to coordinate the operations of the other subsystems on the vehicle and communications between the vehicle and the remote operator control station. An important goal of this research is the standardization of the control architecture so that independently-developed systems can be easily integrated and software and hardware can be exchanged between different projects.
CATEGORY: Robotics, Sensors, Controls

TITLE: Advanced Robotic Deburring and Chamfering
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: NIST has developed automated finishing systems which use CAD data to generate robot programs, and has refined techniques to integrate sensory feedback into the real-time control of deburring and chamfering. Efforts are currently underway in the Advanced Deburring and Chamfering System to automate the finishing of Navy aircraft engine components, such as turbine blades and rotors machined from inconel and titanium, whose hardness and complexity challenges commercial robotic finishing systems. The approach is to use a conventional industrial robot as a coarse positioning device, while relying on an instrumented chamfering tool which is independently controlled to provide variable force and stiffness at the edges. NIST researchers are working jointly with the aerospace industry in this program, blending NIST's experience in robot control and sensor integration with the expertise of industry in the fabrication and finishing of aircraft engine components, so that the next generation of Navy aircraft engines can be manufactured with a quality unmatched in the past.
CATEGORY: Robotics, Sensors, Controls

TITLE: AMRF Composites Workstation
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The focus of this project is the application of sensor-based hierarchically controlled robot systems to automated fiber placement of thermoplastic composite materials. In such a system, continuous fiber reinforced thermoplastic polymer is fed from a spool and applied onto a mandrel or part form. The orientation of the fiber is based on the part's geometry and structural design. As the composite material is applied, it is heated to melt the polymer matrix, and then consolidates in place as it cools. The intention of this project is to demonstrate that the use of fiber placement via two cooperating robot manipulators and in-situ consolidation, can provide the capability to efficiently produce complex shaped composite parts.
CATEGORY: Robotics, Sensors, Controls

TITLE: Cleaning and Deburring Workstation
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: In the Cleaning and Deburring Workstation, techniques have been developed to automate robot programming for deburring, buffing, cleaning, and pan handling. Research conducted in this workstation has resulted in the development of a system that allows robot paths to be automatically computed from CAD part geometry data. In contrast to teach programming, where the robot is manually moved to a desired point and its location recorded for playback at a later time, programming from CAD data requires minimal operator intervention and significantly reduces robot teaching time. For small-batch manufacturing, this means that the programs to process new parts can be generated quickly and inexpensively. Another area of research includes the development of error-correcting methods for minimizing the effects of robot kinematic errors and discrepancies between the software models and the actual conditions in the workstation. Force feedback is used to correct for kinematic error, minor part misplacement, and brush wear. Another approach is to use a map of the robot kinematic errors to correct the downloaded paths before they are executed by this robot. These methods reduce the positional errors of the robots down to the level associated with conventional teach programming.
CATEGORY: Robotics, Controls

TITLE: Space Station Robotics
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is to assist NASA and its contractors in the development of robotic systems and their controllers for space applications. Specifically, this involves the implementation of the NASA/NBS Standard Reference Model (NASREM) architecture for the Flight Telerobotic Servicer (FTS). NIST tasks include demonstrating various control strategies and algorithms implemented follo~ing the NASREM architecture to control a seven degree-of-freedom robot and reviewing contractor-developed designs for the FTS robotic hardware and its control system. In addition to the basic NASREM architecture research, this project involves the development of advanced manipulaiion techniques and the use of machine vision as feedback to the control system to perform such tasks as object tracking.
CATEGORY: Robotics, Sensors, Controls

TITLE: Air Force - Rapid Runway Repair Robotics
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is to assist the Air Force and its contractors in the development of a control system and the necessary sensors to perform autonomous assessment and repair of aircraft runways for the Rapid Runway Repair (RRR) program. This research builds upon the real-time control system (RCS) research performed at NIST over the past decade. Initially applied to automated manufactunng and robotics, the RCS is being evaluated for the control of a large excavating system for repairing runways. NIST tasks include the evaluation of various sensor technologies, especially laser scanning ranging devices, for damage assessment and vehicle navigation and the application of RCS to the control of the RRR system.
CATEGORY: Robotics, Sensors, Controls

TITLE: Manufacturing Systems Integration/Robot Plan Generator
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: One of the major obstacles in the automation of manufacturing systems is the integration of the various components into a single, fully functioning system. For even a moderately complex system, it is difficult and costly to get each of the systems up and running simultaneously to even begin the integration testing and debugging process. This research project involves the development of a simulation approach to solving the interface and integration problem. Testing and debugging are done using simulation of each of the workstation subsystems before attempting to integrate the actual workstation hardware. This greatly simplifies the development and debugging of interfaces and speeds up the integration process. Once the interfaces have been tested, the actual hardware is then substituted for the simulation to verify proper operation. Related to this efforl is the use of this simulation system to automatically develop robot programs off-line. Such an approach has two major advantages in terms of safety and of minimizing robot down-time while an operator is teach programming the robot. Safety is improved because the time required for an operator to actually be in the workstation programming the robot is reduced or eliminated, and potentially damaging errors in the programs can be detected in simulation rather than by running the actual equipment.
CATEGORY: Robotics, Controls

TITLE: Intelligent Control of Mining Machines
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is to assist the U.S Bureau of Mines and its contractors in the assessment of technologies for the Coal Mining Automation Project. This research is based upon the real-time control system (RCS) research performed at NIST over the past decade. Initially applied to automated manufacturing and industrial robotics, the RCS methodology is being adapted to develop an overall control architecture for coal mining operations and extended to illustrate the control of a coniinuous mining machine. This research has resulted in the development of a standard control system architecture, termed the Mining Automation Standard Reference Model (MASREM), which is similar to the NASREM reference model adopted by NASA as a control system architecture standard for all Space Station robotic systems. The goal of this research is to provide a standard control system architecture that will provide a means for automating various mining subsystems and integrating these components into an automated mining operation.
CATEGORY: Controls

TITLE: U.S. Army Materials Handling Robotics Testbed
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is to assist the U.S. Army and its contractors in the development of a robotics-based material handling research testbed. This system is currently configured for manipulating palletized material. NIST previously developed a suite of sensors and control system to autonomously locate and acquire such palletized loads using a large industrial robot. This control system is based upon the real-time control system (RCS) research performed at NIST and initially applied to automated manufacturing and industrial robotics. A U.S. Army contractor fabricated a full-scale robotic device for handling large payloads at extended reaches and demonstrated this system in a manual mode. NIST is now integrating the control system and sensors onto the full-scale system. Based upon these tests, NIST will then develop an upgraded control system using improved hardware and software now commercially available. This system will be demonstrated handling fully loaded ammunition pallets at a U.S. Army testing facility.
CATEGORY: Robotics, Sensors, Controls

TITLE: DARPA Submarine Technology Program
ORGANIZATION/CONTACT: NIST/MEL/RSD; Dr. James S. Albus
PROJECT SUMMARY: The objective of this research is to assist the Defense Advanced Research Projects Agency (DARPA) and its contractors in the assessment of automation technologies for the Submarine Technology Program. This research is based upon the real-time control system (RCS) research performed at NIST over the past decade. Initially applied to automated manufacturing and industrial robotics, the RCS methodology is being adapted to develop an overall control architecture for submarines. NIST tasks include demonstrating various control strategies implemented following the RCS architecture and reviewing contractor-developed designs for the control of submarine systems. The goal of this research is to demonstrate a standard control system architecture that will provide a means for integrating various submarine subsystems and automating overall operations.
CATEGORY: Controls

U.S. DEPARTMENT OF ENERGY'S EFFORTS IN INTELLIGENT PROCESSING EQUIPMENT

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ABSTRACT

The Department of Energy (DOE) uses intelligent processing equipment (IPE) technologies to conduct research and development and manufacturing for energy and nuclear weapons programs. This paper highlights several significant IPE efforts underway in DOE. IPE technologies are essential to the accomplishment of DOE's missions, because of the need for small lot production, precision and accuracy in manufacturing, hazardous waste management, and protection of the environment and the safety and health of the workforce and public. Applications of IPE technologies include environmental remediation and waste handling, advanced manufacturing, and automation of tasks carried out in hazardous areas. DOE laboratories have several key programs that integrate robotics, sensor, and control technologies. These programs embody a considerable technical capability that also may be used to enhance U.S. industrial competitiveness. DOE encourages closer cooperation with U.S. industrial partners based on mutual benefits. This paper briefly describes technology transfer mechanisms available for industrial involvement. An appendix lists projects representative of major IPE activities underway at DOE laboratories and includes a brief description and point of contact for each.

DEPARTMENT OF ENERGY'S MISSION

The Department of Energy (DOE), supports the search for fundamental knowledge, and translates that knowledge into practical applications for the U.S. economy and U.S. defense. The Department is responsible for long-term, high-risk research and development of energy technologies, energy conservation technology development, and the nuclear weapons program.

DOE has applied intelligent processing equipment (IPE) to automate the performance of tasks in restricted hostile environments associated with the R&D and manufacturing of defense systems, energy systems (nuclear and fossil), hazardous waste remediation, and other hazardous activities that normally require the use of skilled labor. The advancement of IPE technology is fundamental to the accomplishment of several of DOE's missions. For example, the use of IPE technology can reduce worker exposure to toxic and radioactive material. IPE technology also is used in the development and manufacturing of weapon systems and nuclear reactors because of required precision and accuracy in manufacturing. As a result, significant efforts in IPE development and implementation are underway within the DOE complex.

This paper does not attempt to cover all the efforts underway within DOE's programs, laboratories, and facilities, but represents some of the most significant activities. The purpose of these highlights is to increase awareness of DOE activities that may be of mutual benefit to DOE and the private sector, and identify potential opportunities for collaboration. The DOE offices engaged in advanced manufacturing R&D provided information describing their IPE efforts for inclusion in this paper. The DOE National Laboratories performing IPE technology development also provided project descriptions. Appendix A provides a list of projects with brief technical abstracts and points-of-contact. References listed after the paper include program plans and other more comprehensive descriptions of activities that are available.

DOE is home to over 23,000 scientists and engineers who perform over $6 billion of research and development annually. DOE's programs, laboratories and facilities are national resources that lend significant scientific, engineering, and technological know-how in achieving broad national energy R&D goals and enhancing U.S. industrial competitiveness through technology transfer efforts. The laboratories and facilities are an integrated network that supports each mission of DOE's programs.

Defense Programs, Nuclear Energy, and Environmental Restoration and Waste Management are three DOE programs with substantial interest in IPE technologies. The development and implementation of these technologies support the advancement of the programs elaborated below.

The Office of Defense Programs manages the nuclear weapons program for the DOE and conducts a range of integral national security. Defense Programs' mission encompasses the design, development, production, and testing of nuclear weapons; technology transfer; and special nuclear materials production and transportation. Defense Programs is one of the few Federal programs that advances technologies from basic research completely through to product production and testing. The development of IPE Technology is an integral part of Defense Programs' mission. Due to Defense Programs' role in weapons development, production, and testing, there is considerable interest and benefit in implementing IPE technologies for all aspects of manufacturing. Defense Programs' efforts in IPE include intelligent process control of plutonium ion exchange systems, spatially resolved force sensors for slip detection, and intelligent process control for automated welding, machining and assembly.

The Office of Nuclear Energy is responsible for administering advanced technology programs and projects related to nuclear power generation, alternative fuel cycle concepts, power systems for space purposes, and nuclear waste technology. The program is particularly interested in IPE contributions to the development of robotics for advanced reactors. One area where the Office of Nuclear Energy is supporting the development of advanced robotics is through the Oak Ridge National Laboratory's University Program.

DOE established the Office of Environmental Restoration and Waste Management in 1989 to coordinate efforts to remediate environmental problems at DOE facilities. The goal of the Office of Environmental Restoration and Waste Management is to ensure the elimination or reduction of risks to the environment and human health from past, present, and future operations. The intent of the program is to develop faster and more cost-effective solutions to environmental restoration and waste management problems. The Office of Environmental Restoration and Waste Management is working on the development and use of IPE technologies to support waste remediation and other goals. For example, Sandia National Laboratories and the Oak Ridge National Laboratory have demonstrated control algorithms for rapid swing-free movement of simulated waste containers coupled with computer control of large gantry bridges. This application decreases the time for material movement and increases safety by eliminating the potential for collisions of swinging payloads. In this example, the implementation of IPE technology enhances the safety and welfare of the labor force.

The Office of Energy Research supports many scientific user facilities used by universities and private-sector researchers, manages DOE's Small Business Innovation Research (SBIR) Program, and directs fundamental science and basic energy research programs in several areas, including high-energy physics; nuclear physics; the physical, biological, and mathematical sciences; magnetic-fusion energy; and environment and health. The Office of Energy Research and other DOE program offices also have small efforts underway in IPE technologies.

INTEGRATED IPE PROJECTS

The separation of IPE technologies into categories of robotics, sensors, and controls is often difficult when the technologies are integrated into systems for specific applications. There are several such efforts underway within DOE. The programs give the scientist or engineer a unique opportunity to work across the entire field of technologies involved, and also across the DOE complex, and with industry and university staff. One example is the Oak Ridge National Laboratory University Program.

Oak Ridge National Laboratory University Program

The Office of Nuclear Energy supports four universities and the Oak Ridge National Laboratory in research, development, and deployment of an advanced robotics system capable of performing tasks within restricted hostile environments such as those encountered in nuclear power plants. This new generation of advanced robotics systems is intended to perform surveillance, maintenance, and repair tasks in advanced nuclear power plants. The effort is carried out in close collaboration with both ongoing advanced reactor development programs and utility companies operating nuclear power stations. An integrated team composed of the universities of Florida, Michigan, Tennessee, and Texas, industrial partners, and Oak Ridge National Laboratory has been working toward this objective.

Each team member provides a crucial element to the overall program. Oak Ridge National Laboratory fulfills a dual role, serving as the program coordinator and system integrator, and performing R&D in key areas of advanced robotics, such as range-sensor-based 3-D world modeling, sensor fusion, and concurrent computing. Figure 1 shows the Hermies III (left) and the Hermies IIB at work in the Oak Ridge National Laboratory's Mobile Robot Research Laboratory. The University of Florida is contributing in locomotion and navigation, 3-D plant modeling, environmental hardening of system components, and robot intelligence. The University of Michigan performs R&D in radiation imaging and navigation -- choosing tasks and moving the robot safely and efficiently within a radioactive environment to the target worksite. The Computer Vision and Robotics Laboratory at the University of Tennessee is contributing in robot vision and sensing for manipulation and multi-sensor integration. The University of Texas at Austin is focusing on the dynamics, control, and design of modular robot manipulator systems.

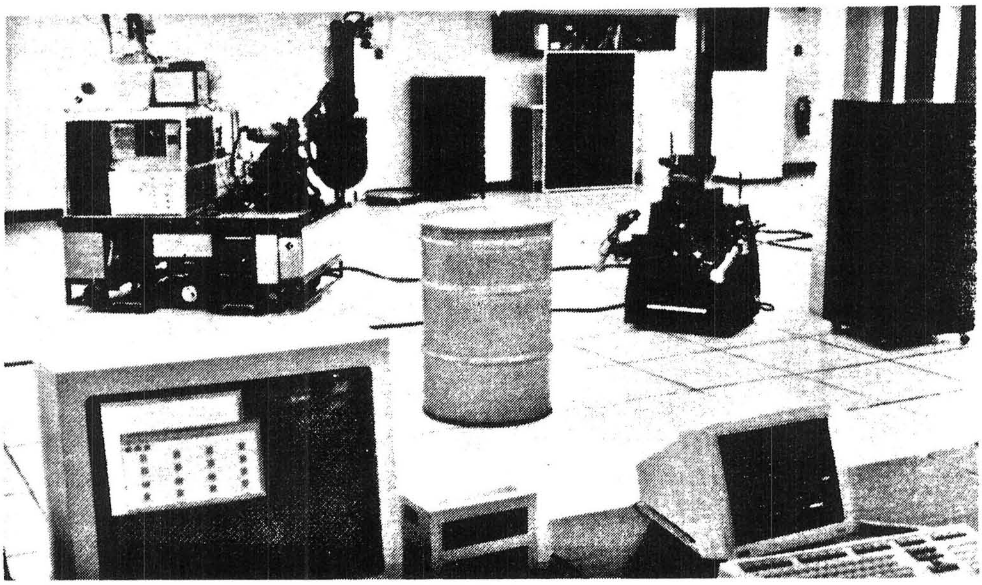

Figure 1: Oak Ridge National Laboratory's Mobile Robot Research Laboratory

Robotics Technology Development

The Robotics Technology Development program is a conducted by the Office of Environmental Restoration and Waste Management. The objective of the program is to work with DOE sites to develop needs and requirements, and carry out research, development, demonstration, testing, and evaluation in DOE laboratories and with U.S. industry partners.

The Robotics Technology Development program has work underway in exploring master-slave manipulators, servomanipulators, remotely operated heavy equipment (e.g., bridge cranes and excavators), special remote tooling and industrial-type programmable robots, mobile platforms and transporters, sensing systems, and control systems. The technologies are used to solve problems related to remediation of waste storage tanks, retrieval of buried wastes, automation of contaminant analyses, waste minimization, decontamination and decommissioning, and waste handling operations. Examples of projects currently underway are mapping of buried waste sites using a teleoperated vehicle with advanced sensing technologies and scaled waste tank remediation.

Precision Flexible Manufacturing Systems (PFMS) Program

The DOE Albuquerque Field Office established the cooperative Precision Flexible Manufacturing Systems program to develop and provide critical technologies for the remote manufacturing and in-process certifying of precision components. The long-range goal is to develop technologies for the remote fabrication of components involving toxic, radioactive, or other hazardous materials.

DOE's weapons plants and laboratories, the National Institute of Standards and Technology (NIST), and private industry partners are participating in the development of remote prototype systems. Los Alamos National Laboratory is developing a Precision Automated Turning System (PATS) for the remote manufacturing of precision stainless steel components. Lawrence Livermore National Laboratory is developing a certification of process (COP) gage.

Sandia's Defense Programs National Center for Excellence in Robotics

DOE Defense Programs has designated Sandia National Laboratories as a Center of Excellence for Robotics and Automation. The Center's focus will be on developing IPE technologies for use in small lot production of very precise and accurate parts.

The Center has a two-part approach to providing systems that will be effective in the small lot production environment. Technologies being developed allow the software for programmable automation to be automatically developed; that is, the systems generate their own plans and programs. The second part of the approach is the addition of sensor- and model-based control, which alleviates the requirement for precise fixturing and jigging of piece parts. These types of real-time sensory capabilities enable a number of other desirable features of flexible production systems, such as automated compensation for tool wear, in-process inspection, and automated error detection and correction.

Advanced Manufacturing Initiative

The Advanced Manufacturing Initiative (AMI) is a key element of Defense Programs' technology transfer program. The AMI encompasses all aspects of manufacturing from machine tools to advanced quality control methods. The first effort under this initiative involves the National Center for Manufacturing Sciences (NCMS), the largest research and development consortium in the United States with over 100 member firms. In July, 1991, DOE and NCMS signed a Memorandum of Understanding that forges an alliance between the Defense Programs complex and U.S. industry for collaborative R&D to enhance the industrial technology base. The program focuses on working with U.S. industry partners to accomplish mutually beneficial goals in manufacturing technologies. Intelligent process control for automated welding, machining, and assembly, and intelligent machining of castings are examples of IPE-related projects jointly funded by U.S. industries and Defense Programs under this initiative.

ROBOTICS

Robotics spans a broad range of technologies ranging from manual and remotely operated systems to advanced and autonomous robots. Throughout the DOE laboratories there are several efforts underway exploring applications of robotics to waste management and advanced manufacturing.

Waste Remediation

An area of development extremely important to DOE is robotics for removal and manipulation of hazardous waste. Many environmental restoration and waste management activities involve working in hazardous environments and handling hazardous materials. The work is slow, expensive, and dangerous to personnel to perform manually. Robotics technologies permit workers to stay out of hazardous environments, improve the productivity of remediation operations, and reduce operating costs.

The Office of Environmental Restoration and Waste Management is supporting development of a remote Content Removal Device (CRD) for underground storage tanks. CRD robot technology is being demonstrated at the Fernald production plant in Ohio for the removal of hazardous waste stored in waste tanks and silos. Other waste handling efforts include the development of robotics techniques for performing automated bagout of hazardous materials from gloveboxes.

Laboratory Automation

To meet needs for timely and reliable chemical and isotopic measurements, the Laser Isotope Separation program maintains a captive mass-spectrometry facility at Lawrence Livermore National Laboratory. The facility incorporates a considerable degree of laboratory automation and robotics to assist in tracking materials, preparing samples, obtaining data, and presenting experimental results in formats conducive to understanding system operation. The system consists of a cluster of five personal computers that control the actions and allow data exchange among electro-mechanical devices and laboratory instruments, including electronic balances, digital calipers, bar-code readers, a robot arm, sample dilutors, an inductively coupled plasma mass spectrometer, a thermal ionization mass spectrometer, and a central database.

SENSORS

Sensors provide the necessary input to controllers to provide real-time information for machines to perform their functions. By providing real time information, controllers can identify potential bottlenecks, breakdowns, and other problems with individual machines and/or machine tools. Throughout the DOE complex, scientists and engineers have been developing and integrating sensors into intelligent processing equipment. Work is underway to develop a range of sensor technologies within the DOE complex, e.g., proximity sensors, condition sensors (temperature, stress, and vibration), and position-monitoring sensors. A few examples of current efforts are highlighted below.

Force Sensor

Efficient automated manufacturing requires handling multiple components with high-speed robot systems. The ability of the robot to sense contact with the workpiece is a limitation of current systems. Without contact sensing, the robot performs open-loop manipulation, requiring slow movements using specially designed robot end effectors. Forces of gravity, contact of mating parts, or high-speed robot motion produce unstable contact areas between the robot and workpiece that can result in the object slipping out of the robot gripper. Sandia National Laboratories has developed a spatially resolved force sensor to permit a robot to sense automatically a grasped object and prevent it from sliding out of the end effector during manipulation. Each sensing element can measure uniquely the complete force vector in three dimensions. By automatically preventing slippage, manufacturing processing times can be shortened significantly without concomitant reduction in safety or increase in cost.

Computer Vision

Computer vision is an important component of intelligent processing equipment. Model-based computer vision and feature-based computer vision are two approaches that Sandia National Laboratories is currently developing.

The task-specific nature of current industrial computer vision systems has limited the application of vision technology because variations in workpiece, workcell, or lighting require costly reprogramming. In response, Sandia National Laboratories is developing techniques for robot guidance using model-based vision. Geometric models of objects in the workcell allow the system to interpret features identified in video images. This machine vision system interprets by correlating image features with physical features on an object. The system then computes the three-dimensional object position and orientation most likely to have led to the observed image features. By using multiple views, the system can accurately locate components even when they are partially or fully blocked from some viewpoints. Because the system interprets each image as a monocular image, this approach makes it unnecessary to find correspondences between stereo images. The system uses a sequence of multiple views to improve performance in two ways: it tracks changes in the three-dimensional position of moving objects, and it refines estimates based on additional observations. A prototype system tracks the full six-degree-of-freedom motion of objects manipulated by a robot and locates other modeled objects in the workspace. Researchers are applying the prototype system to robot control of operations such as deburring, surface finishing, and assembly (Figure 2).

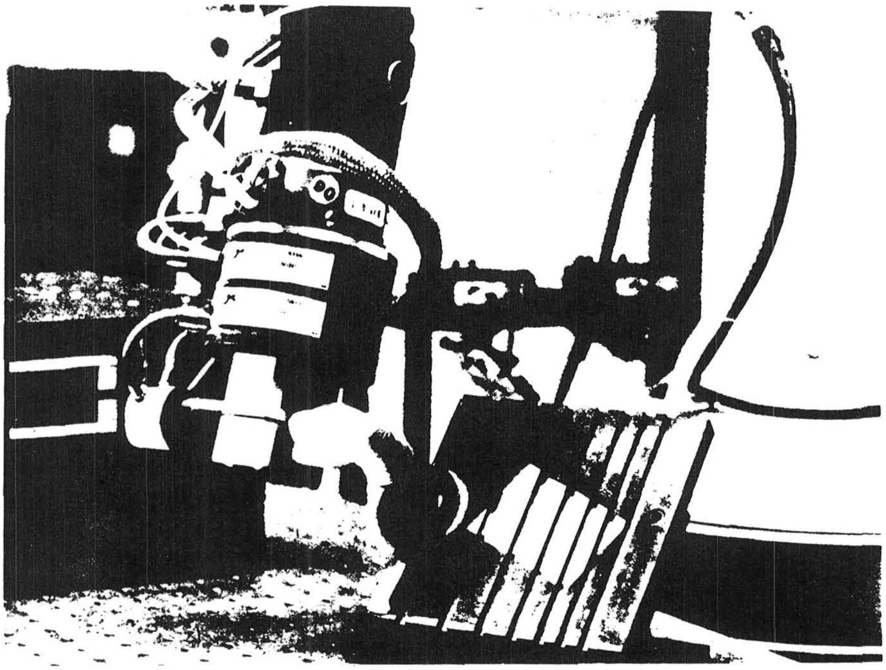

Figure 2: Prototype System for Surface Finishing

Feature-based computer vision systems combine general-feature extraction algorithms with task-specific algorithms in a customized vision solution for a particular task. A variety of robotics activities use vision systems with these feature-based vision algorithms. In the Remote Radiation Survey and Analysis System, a stereo vision system is mounted on a gantry robot located within 0.1 inches of an 8-ft. long scale model shipping container for radioactive waste. In an automated deburring cell, a monocular vision system determines the orientation within 1 degree, of components to be deburred by finding indexing features. An arm-mounted, feature-based vision system locates components for assembly in a workcell demonstrating an assembly planning system.

Non-contact Inspection

The development of non-contact sensors for inspection is essential for achieving high quality manufacturing. Sandia National Laboratories has developed a High-Resolution Capacitive Imaging Sensor (HIRCIS) to permit non-contact inspection of small surface features on a variety of objects. A 16-element prototype array of a HIRCIS device can preview and inspect burrs that remain on the edge of complex mechanical parts. A robot mechanically scans the HIRCIS array over the desired edge, and communicates the data in real time to a graphics display. The HIRCIS has been demonstrated in applications requiring monitoring of edge chamfer dimensions, weld bead shape, and metal corrosion. The ability to sense the surface profiles of a workpiece on line and in real time permits quality improvements and reduced waste through closed-loop control of the manufacturing process.

In another project, Sandia National Laboratories is evaluating and implementing non-contact full-field sensors for real-time determination of temperature and distortion in the production environment. These efforts are in support of developing a first generation intelligent processing system (IPS) to control distortion in thin-section welded assemblies. The objective of the IPS is to provide welding and design engineers with an integrated sensor or model methodology for assessing weld ability of a part.

Los Alamos National Laboratory is developing non-invasive, on-line sensors for intelligent process control of sintering ceramics, with the objective of improving quality in ceramic part manufacturing. An experimental apparatus has been designed and built to measure ceramic materials during sintering up to 1500°C. With this device, researchers can investigate the changes in microstructure during the sintering process.

CONTROLS

Controllers act as the "brains" of intelligent processing equipment by manipulating equipment task through the interpretation of sensor input. Controllers use Advanced processor chips and software languages to command and control multiple functions simultaneously.

Motion Control

In manufacturing applications, a lighter robot can manipulate a larger range of payloads at higher speeds. However, a lighter robot also exhibits flexible characteristics that cannot be controlled with standard robot joint control techniques when used at normal speeds. Using control techniques developed at Sandia National Laboratories, lighter weight, more flexible robotics arms become inherently safer than rigid arms. Another potential application of the research could enable more accurate positioning of flexible parts such as gaskets and O-ring assemblies. Sandia National Laboratories has developed three control techniques that allow flexible structures to move at high speeds and still arrive at the destination in a vibration-free state. The first algorithm provides open-loop control of oscillations in a single-link, flexible structure, having significant sag due to gravity. The algorithm controls the acceleration and velocity profiles for the required move in a direct relationship to the natural first mode of oscillation for the flexible structure. The second technique employs a dynamic model of the structure, an off-line optimization program, and sensor feedback to control multilink robotics arms along specified oscillation-free trajectories in minimum time. The third method uses a filtering technique to modify the input from a joystick to eliminate residual vibration.

Operations involving the handling of hazardous materials such as radioactive or explosives materials in U.S. industry require the use of remote systems under the control of an operator to minimize worker exposure to hazards. Force-controlled operations allow rapid completion of these remote tasks while preventing the application of excessive forces that might lead to equipment damage. In addition, force control allows the automation of many high-tolerance mechanical assembly operations that were previously not feasible. Sandia National Laboratories has developed algorithms, based upon kinematic and dynamic models of the robot, that are used to compute the positional commands needed to generate the proper robot motion to achieve a desired contact force. The approach constructs a force controller around the basic position controller supplied with most commercial robots.

Monitoring Control

Intelligent process monitoring and control methods may be applied to a variety of manufacturing processes to increase product quality and reduce waste. An intelligent process monitoring and control system could be used to control the production of plated metals or chemically milled metals. Sensors obtain data about chemical and physical variables that affect the production process and product quality. A model of the production process then uses the sensor data to calculate adjustments for process control variables, such as temperature, mixture composition, and residence time, to obtain the desired product quality. Sandia National Laboratories has developed software control technology to facilitate the use of information from a variety of sensors for process monitoring and control. The software architecture is designed to isolate programmers and users from the details of sensor-specific information. The C high-level language allows commercial software libraries to be used for graphic display and data communications.

Other efforts in controls, underway at Idaho National Engineering Laboratory for the Nuclear Energy program, focus on intelligent control of materials processes, intelligent control of nonlinear processes and a programmable automated welding system. These efforts are incorporating and developing advanced sensors in control system logic.

TECHNOLOGY TRANSFER MECHANISMS

Although technology transfer has always been an element of DOE and laboratory activities, it has received increasing emphasis within DOE in recent years as U.S. industrial competitiveness has eroded and efforts have increased to utilize the research and development resources of the DOE National Laboratories better. There are several mechanisms that industry can use to access DOE technologies. These include Cooperative Research and Development Agreements (CRADAs), user facility agreements, work for others, workshops, demonstrations, and consulting. DOE's scientific and technical information is available through publications and on-line retrieval systems, supported through the Office of Scientific and Technical Information.

Under the Federal Technology Transfer Act (FTTA) of 1986, Congress created CRADAs to facilitate collaboration between government agencies and industry. In 1989 the National Competitiveness Technology Transfer Act (NCTTA) made it possible for DOE's Government-Owned, Contractor-Operated (GOCO) research and development laboratories to enter into CRADAs. In 1990, DOE began to implement the provisions of the NCTTA, including the successful negotiation of new contract clauses regarding technology transfer responsibilities of the laboratories.

CRADAs represent a departure from traditional Federal technology transfer mechanisms. CRADAs provide the private sector partner with an option in advance to negotiate exclusive licenses to inventions made under the agreement, and allow proprietary data or information brought into or developed during a research program to be held confidential for up to five years. Typically, the work done under a CRADA is cost-shared between the private sector partner and the sponsoring Federal program. Laboratories enter into a CRADA only when the research objective is consistent with the laboratory's mission. Ultimately, the private sector partner is responsible for commercialization of any new product, process or service that results from the collaboration.

Another mechanism for technology transfer is through licensing of patents. Technologies may be licensed from the DOE or the National Laboratories, under negotiated terms, on an exclusive, exclusive for field-of-use, or nonexclusive basis. Work-for-others and user facility agreements give private industry the opportunity to work with unique expertise and technical resources available in DOE on projects of direct interest to the private sector participant. These programs are typically funded exclusively by the private sector participant, and must not compete with capabilities available in the private sector. Other technology transfer mechanisms include laboratory staff consulting, educational or industrial internships, subcontracts and procurements, grants, and technical information exchange.

The development of IPE technology within the DOE complex is vital to maintaining the technology base to fulfil the individual program missions of DOE. The efforts in IPE are complex wide. Appendix A represents several efforts underway in DOE in IPE technologies. DOE is interested and encourages closer relations based on mutually beneficial interactions with private sector partners.

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Available from U.S. Government Printing Office (S/N003-009-00586-8) Telephone: 202/783-3238.

DEPARTMENT OF ENERGY
POINTS OF CONTACT & IPE PROJECT ABSTRACTS

U.S Department of Energy — 615/576-8401
Office of Scientific and Technical Information
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NATIONAL LABORATORY'S TECHNOLOGY TRANSFER CONTACTS
(List reflects only those laboratories which were referenced.)

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Sandia National Laboratories
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P.O. Box 5800
Albuquerque, NM 87185

CATEGORY: INTELLIGENT PROCESSING EQUIPMENT

TITLE: Assembly of Explosive Components

Patrick Eicker — 505/844-5827
Sandia National Laboratory, Department 1410

Sandia National Laboratories and EG&G Mound Laboratories, a Department of Energy production facility, are developing an automated workcell to reduce operator exposure and increase productivity. The approach is to integrate existing computing, sensing and robotic technology into an automated powder weighing-loading-pressing system.

TITLE: Automated Edge Finishing of Uranium Components
George Pappas
Department of Energy, Albuquerque Operations Office, Weapon Quality Division

Edge finishing, both deburring and chamfering, of uranium components is presently performed manually at Y-12. Manual deburring of uranium has been identified as a significant potential operator health hazard at Y-12 due to radiation exposure and airborne uranium particles. The approach is to integrate existing, but not commercially available, sensing and robot control technology with a commercially available robot, tooling, and CAD system.

TITLE: Precision Flexible Manufacturing Systems (PFMS) Program
Donald L. Plymle 505/845-9203
Sandia National Laboratories

The long-range goal is technology for the remote fabrication of such components from toxic, radioactive, and hazardous materials. The program has three phases: (1) demonstration of critical technology; (2) demonstration of a prototype; and (3) inauguration of remote manufacturing. Participants are plants and laboratories in the DOE weapons complex, the National Institute of Standards and Technology (NIST), and U.S. private industry.

TITLE: Robotic Disassembly of Nuclear Weapons
George Pappas
Department of Energy, Albuquerque Operations Office, Weapon Quality Division

Contact handling of the radioactive components results in high occupational radiation exposure to the disassembly technicians. There is also a safety hazard associated with manual handling of high explosive components. The approach is to use existing commercially available robotic technology, integrated with sensors and computing subsystems to manipulate special handling fixtures.

TITLE: U.S. DOE University Program in Robotics for Advanced Reactors
Harry Alter 301/903-3766
Department of Energy, Office of Nuclear Energy, Advanced Technology Office of Technology Support Programs

DOE is University program in robotics for advanced reactors involves a unique arrangement among the Universities of Florida, Michigan, Tennessee, and Texas, their industrial partners, and Oak Ridge National Laboratory. The next-generation intelligent robotic systems developed under this program are important in ensuring mixed and balanced energy supply for the United States.

CATEGORY: ROBOTICS

TITLE: Alignment of KRF Laser Facility
Burt Kortegaard 505/665-3316
Los Alamos National Laboratory, MEE-12

Self adopted optimal 96-beam laser alignment system that was orders of magnitude better. More reliable and cheaper than anything commercially available. Used video imaging. 96 systems were measured on single camera.

TITLE: Automated Programming Module
Van B. Graves 615/576-3690
Oak Ridge Y-12 Plant, Development Division

Using automated programming module (expert system) for equipment inspection.

TITLE: Intelligent Machining of Castings
Cliff Loucks 505/846-9625
Sandia National Laboratories, Org. 1411

This project involves adaptive machining of cast turbine blades. Due to uncontrollable warpage during solidification of cast parts, each part has unique dimensions. A structured lighting sensor will discern the unique geometry of each part. The processed data will be used to generate the unique tool paths required to perform high precision machining operations on the tip of the blade.

TITLE: Remote Content Removal Device (CRD) for Underground Storage Tanks
Claire Sink 301/903-7928
U.S. Department of Energy, EM-521, Office of Technology Development

Robotics technology is being demonstrated at Fernald Production Plant to remediate waste storage tanks and silos and to remove the hazardous waste that is stored in them. The robotics technology will be used to develop an off-the-shelf CRD to be integrated with computer controllers, peripheral sensors, and modelling/control software.

TITLE: Robotic Edge Finishing
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

In the Sandia system, a CAD model of the workpiece automatically generates the robot paths. Replacing precise fixtures with inexpensive clamps is possible through a machine vision system used to located and report the workpiece position. Additionally, the deburring a chamfering processes are feedback controlled by sensing and maintaining the proper tool contact force.

TITLE: Robotic Handling of Large Heavy Components
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

An important part of the program is the development of robotic technologies to allow the handling of large, heavy objects. Prototype systems have demonstrated bolting and unbolting, assembly and disassembly, mating and docking, uprighting and placement as well as the oscillation-damped movement of large objects.

TITLE: Robotic Laboratory Automation
B.M. Wilding
Idaho National Engineering Laboratory

The Robotic Laboratory Automation program was established to develop automation technologies to meet the need for characterization of environmental samples. Analysis methods have been defined by their basis functions. These basic functions are made into automated modules. The modules arrangement meets the specific analysis method.

TITLE: Robotic Surface Finishing
Patrick Eicker — 505/844-5827
Sandia National Laboratories, Department 1410

Robot tool trajectories, automatically generated from a CAD description of the workpiece, are transformed in real time to conform to the location of the workpiece. Simple clamps can now replace expensive fixtures to secure the work for processing. The process is controlled by using the contact force between the abrasive tool and the part as the tool is fed across the surface.

TITLE: Robotics Technology Development
Claire Sink — 301/903-7928
U.S. Department of Energy, Environmental Restoration and Waste Management Program

Robotics includes robots, servomanipulators, mobile platforms, and advanced automation equipment. Activities include advanced robots that make use of computer control based on sensor feedback. Computer technologies include graphics interfaces, real-time modeling and control data management, and shared human/computer control. Sensory inputs include force, proximity, vision, and navigation.

TITLE: Robotics Waste Minimization
Claire Sink — 301/903-7928
U.S. Department of Energy, EM-521, Office of Technology Development

Intelligent robotic and automation technologies to minimize the waste steams associated with hazardous materials handling operations. IPE technology is being developed to improve process control and to adjust process parameters. Early demonstration of intelligent systems will focus on robotic plutonium glovebox operations to reduce waste associated with manual operations.

TITLE: Sensor-Based Glovebox Operations
Patrick Eicker — 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed robotic techniques for performing bagout of hazardous materials from gloveboxes. An integrated force sensor, a radiation monitor, and a supervisory computer program that requires preauthorization to allow bagout enhances strategic materials accountability.

TITLE: The Use of Robotics and Laboratory Automation in Assessing the Performance of AVLIS Isotope Separators
Philip Miller — 510/543-2348
Lawrence Livermore National Laboratory

To fulfill its needs for timely and reliable chemical and isotopic measurements, the LIS program maintains a captive mass-spectrometry facility. This facility incorporates a considerable degrees of laboratory automation and robotics to assist in tracking materials, preparing samples, obtaining data, and presenting experimental results in formats conducive to understanding system operation.

CATEGORY: SENSORS

TITLE: Automated Weld Control Based on Real-Time Weld Imaging
Leonard Napolitano 415/294-3218
Sandia National Laboratories, Org. 8432

The program goal is to control the weld electrode position automatically with respect to the surfaces to be welded. The control is done by using a video camera as the sensor to view the welding process, and then performing high speed image processing to extract weld pool dimensions and welding electrode to weld pool distance.

TITLE: Automatic Measurement of Residual Stress Using Single-Axis Holographic Blind Hole Drilling
Beth Fuchs 510/294-2705
Sandia National Laboratories, Mechanics of Materials Division, 8246

A promising new method of residual stress measurement method takes the best features of the blind hole drilling technique and combines those features with the use of holographic interferometry to create a new method that is fast and accurate. The technique is versatile and could be used to evaluate residual stresses caused by numerous manufacturing and fabrication processes.

TITLE: Echelle Spectrograph Software
Patrick Epperson
Lawrence Livermore National Laboratory

We are writing software to analyze spectral images from a DC arc to determine the elemental composition of solid samples. The software will measure several atomic emission lines for each element of interest. The detector is a 1024 b_T 1024 element CCD array detector. The objective is to make better measurements of trace metal concentrations in complex solid samples.

TITLE: Feature Based Computer Vision
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Feature-based computer vision systems combine general-feature extraction algorithms with task-specific algorithms in a customized vision solution for a particular task. Sandia has developed a variety of feature extraction algorithms for these purposes and has integrated these algorithms into robot systems for assembly, automated deburring, and handling of hazardous waste.

TITLE: Fiber Optic Sensing of Polymer Composite Curing
Dr. R. Lyon
Lawrence Livermore National Laboratory

Microfiber optic sensing of the curing process for matrix materials in polymer base fiber composites. Curing characteristics are diagnosed using Raman spectroscopy. Results in drastically improved uniformity of properties and reduction in reject rates.

TITLE: High Resolution Capacitive Imaging Sensor
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia developed the High-Resolution Capacitive Imaging Sensor (HIRCIS) to permit noncontact inspection of small surface features on a variety of objects. HIRCIS senses variations in capacitance due to changes in the surface profiles of metal, composite, ceramic, and plastic workpieces.

TITLE: Integration and Application of Multisensor Systems
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Multisensor integration is the combining of information from multiple sensory devices to assist in accomplishing a task. This broad definition pertains to all aspects of the integration process, including sensor fusion techniques, organization of sensor modules, sensor selection strategies, generic architectures for hardware and software, and control structures for sensor integration.

TITLE: Intelligent Control in Thin-Section Welded Assemblies
K.W. Mahin and M.L. Callabresi
510/294-2064
Sandia National Laboratories

The objective of the intelligent processing system, is to provide welding and design engineers with an integrated sensor/model methodology for assessing the weld ability of a part. Noncontact full field sensors for real time determination of temperatures and distortion in the production environment are being evaluated and implemented for manufacturing applications.

TITLE: Intelligent Process Control for Automated Welding, Machining and Assembly
James L. Novak 505/844-4227
Sandia National Laboratories, Org. 1411

Wide variations in part variables result in processes which are difficult to perform automatically and involve large labor costs. The High Resolution Capacitive Imaging Sensor (HIRCIS) will permit improved process control by providing real-time feedback about the workpiece geometry to welding, machining and assembly processes.

TITLE: Metal Transfer in Gas Metal ARC Welding
Professor T. Edgar 617/253-1000
Massachusetts Institute of Technology

The present research is part of a cooperative program among faculty at MIT and the Idaho National Engineering Laboratory to develop a sound understanding of the arc welding process and to develop sensing and control methods that can be used to automate the gas-metal arc process. Work has led to a new hypothesis to explain the transition from globular to spray metal transfer.

TITLE: Microelectrode Arrays for Monitoring
Keith C. Hong 415/294-4441
Lawrence Livermore Laboratory, Chemistry and Materials Science Department

The researchers have chemically modified some of the surfaces of the microelectrodes to increase sensitivity and selectivity toward specific analysis. Using an array of electrodes one can detect multiple species. Various electroanalytical techniques could then be used to determine concentration of toxic species in water.

TITLE: Model-Based Computer Vision
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Geometric models of objects in the workcell allow the system to interpret features identified in video images. This machine vision system interprets by correlating image features with physical features on an object. The system then computes the three-dimensional object position and orientation most likely to have led to the observed image features.

TITLE: Multivariable Control of the Gas - Metal ARC Welding Process
Professor D. Hardt 617/253-1000
Massachusetts Institute of Technology

The Gas-Metal Arc Welding Process is a highly productive means for joining metals and is being used increasingly for structures and pressure vessels. The overall objective of this work is to examine the problem of simultaneous regulation of all real-time attributes of a weld. Present work is examining the geometric aspects of weld pool control.

TITLE: Nanoscale Lithography Induced by Modified Scanned Probe Microscopy
Mehdi Balooch 510/422-7311
Lawrence Livermore National Laboratory, L-357

Nanolithography will be developed for a variety of electronic materials using modified scanned probe microscopy. Two lithographic techniques will be used depending on material properties. 1) chemical modification, both by chemical etching or by chemical deposition 2) physical modification by processes induced solely by the high current density or by indentation using the sharp tip of AFM.

TITLE: Neural Network Imaging Systems for Commercial Production
John Marinuzzi 505/667-8254
Los Alamos National Laboratory LANL

Neural Networks are trained to recognize defects in quality of commercial production lines. This project is to transfer demonstrated technology at LANL to the private sector.

TITLE: Noncontacting Laser Acoustic Molten Metal Depth Sensing Technology for Hearth Melting
Tim Roney 208/526-9712
Idaho National Engineering Laboratory, Materials Technology Group

This noncontacting sensor will measure the depth of molten titanium during hearth melting to help eliminate stress-intensifying inclusions in metal ingots used in the manufacture of turbine engines. The sensor involves generation/detection of acoustic waves using a pulsed laser (generation) and a continuous wave laser (detection).

TITLE: On-line Sensors for Ceramic Process Control
E.H. Farnum 505/665-5223
Los Alamos National Laboratory, Ceramic Science and Technology Group

The goal of this project is to develop non-invasive, online sensors for intelligent process control of sintering ceramics, with the objective of improving quality in ceramic part manufacture. We are investigating developing microstructure during the sintering process.

TITLE: Portable Acoustic Wave Sensor (PAWS) System
Greg Frye 505/844-0787
Sandia National Laboratories, Org. 1315

Portable acoustic wave sensor systems are being developed for real-time, on-line monitoring of chemical concentrations in industrial process and waste streams. Using absorptive polymer coatings, rapid and reversible detection of volatile organic species can be achieved. The extreme sensitivity of the acoustic wave device enables sensitive detection of gas phase species.

TITLE: Sensors for Control of Semiconductor-Manufacturing Equipment
Paul Miller 505/844-8879
Sandia National Laboratories, Org. 1126

As one part of Sandia's SETEC contract with SEMATECH we study processes and signatures of semiconductor-manufacturing equipment. The equipment includes plasma and thermal reactors. Electrical and optical probes and signals directly relate to performance and have proven valuable for process control.

TITLE: Sensors for In-Situ Diagnostics
Ross Munchausen 505/665-4949
Los Alamos National Laboratory, CM-EROC

Develop sensors for in-situ diagnostics and controls at pulsed laser deposition of thin films. Diagnostics being developed to monitor deposition rate, and composition.

TITLE: Spatially Resolved Force Sensors for Slip Detection
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed a spatially resolved force sensor to permit a robot to automatically sense a grasped object and prevent it from sliding out of the end effector during manipulation. Each sensing element is uniquely capable of measuring the complete force vector in three dimensions. An array of these devices, distributed over the contact surface, provides a spatial map of the contact forces.

TITLE: Structured Lighting Sensor
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

The three dimensional geometry generated by the structured lighting sensor produces geometric models used in model-based control systems, which are playing an expanding role in robotics in ensuring safety, increasing productivity, and reducing personnel involvement with hazardous tasks.

TITLE: Thin Film Process Monitoring and Diagnostics
Dan Doughty 505/845-8105
Sandia National Laboratories, Org. 1846

Exercising control in the preparation and processing of thin films is often empirically derived. Acoustic wave (AW) technology was applied to the problem of characterizing and controlling thin film properties, with the goal of developing a) novel AW sensors to monitor generic materials processing techniques, and b) chemically selective sensors that could be used for environmental monitoring.

TITLE: Use of Quantitative Infrared Thermography for Monitoring and Controlling Temperature
Beth Fuchs 510/294-2705
Sandia National Laboratories, Mechanics of Materials Division, 8246

Surface temperatures measurements may be determined remotely by measuring the infrared radiation emitted from a specimen. Applications in quantitative infrared thermography have included material modeling, weld modeling, weld process control, temperature mapping for combustion processes and temperature measurement for deposition processes.

TITLE: X-ray Tomographic Microscopy for Advanced Composite Characterization
John H. Kinney
Lawrence Livermore National Laboratory

Tomographic Microscopy (XTM) allows noninvasive, three-dimensional visualization of materials microstructures with extremely high spatial resolution. XTM will augment more traditional characterization techniques such as electron microscopy, and will directly address fundamental questions in advanced composite fabrication and defense nuclear waste treatment.

CATEGORY: CONTROLS

TITLE: Adaptive Machining
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Commercial computer numerically controlled (CNC) machining centers employ an open-loop control structure. Parts are precisely fixtured in place and the machine follows a specific trajectory of the nominal tool tip. The use of open-loop control imposes limits on the breadth of applications of CNC machines. Sandia is currently transferring in-process sensing and control technologies, developed in the Robotic Edge Finishing Laboratory, to a state-of-the-art five axis machining center.

TITLE: Analytical Instrument Development and Data Acquisition
Paul Turner 615/574-0907
Oak Ridge Y-12 Plant, Development Division

A multi-year endeavor to develop artificial intelligence applications, real-time process control, and imaging processing capabilities for the application of analytical instrument development.

TITLE: Applications of Artificial Neural Network to Advanced Manufacturing
Dr. Chi Yung Fu
Dr. George Chapline
Lawrence Livermore National Laboratory, P.O. Box 808 L-271

Our concept, which is based on neural networks and fuzzy logic, represents a radical new approach to manufacturing. The ultimate goal is to produce a "smart" controller with human-like intelligence to monitor and control inherently meta-stable processes, and also to do on-line, real-time diagnostics to predict component failure at an early stage.

TITLE: Arc Welding Feedback Control
A.E. Bentley 415/294-1375
Sandia National Laboratories, Org. 8484

Feedback control is being applied to arc welding in order to improve process capability by making more repeatable welds. This improves weld quality by reducing variations in weld penetration, and also makes the process more efficient by minimizing the need for post weld inspection and costly rework and/or scrap--all of which currently constitute a substantial expense for the welding industry.

TITLE: Automated Processing
Ross Muenchausen 505/665-4949
Los Alamos National Laboratory, CM-ERDC

Develop laser-based process for patterning and modification of thin films for electronic applications. Includes automated process for laser patterning, and surface modification to micron resolution.

TITLE: Automated Robot Motion Planning
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Motion planning is an essential technology to facilitate automatic robot programming. Sandia has developed a generic motion planner that can be easily adapted to robots with arbitrary degrees of freedom. Given a description of the environment and the start and goal positions of the robot, our system can plan a short and collision-free path within minutes for standard robots with six degrees of freedom.

TITLE: Automation of Assembly and Disassembly Using Robots
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia developed the Archimedes system to completely automate the processes in the assembly and disassembly of mechanical systems. Starting with a computer model of the parts and system to be assembled or disassembled, Archimedes develops the plan of operations and the necessary sequencing for the operations. This plan is automatically compiled into a robot program.

TITLE: Cartesian Control of a Remote Manipulator
Patrick Eicker 505/844-5827
Sandia National Laboratory, Department 1410

The Schilling Titan 7F™ is a lightweight (135-lb) midsized robotic manipulator with a payload of 400 to 1200 lb. The commercially available motion control for the Titan is a kinematic master that allows the operator to move individual joints of the manipulator. Sandia has developed a Cartesian control system for the Titan 7F™, which replaces the kinematic master.

TITLE: Flexibility Control
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed three control techniques that allow flexible structures to move at high speeds and still arrive at the destination in a vibration-free state. One of the three algorithm provides open-loop control of oscillations in a single-link.

TITLE: Force Controlled Manipulation
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia-developed algorithms, based upon kinematic and dynamic models of the robot, are used to compute the positional commands needed to generate the proper robot motion to achieve a desired contact force. The approach developed by Sandia constructs a force controller around the basic position controller that is supplied with most commercial robots. A force/torque sensor integrated into the robot's structure at the wrist senses contact forces and torques during robot operations.

TITLE: Geometric Modelling
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed basic algorithms for carrying out geometric modeling operations on advanced parallel-processing computers. Working with a new data structure that represents solids, these algorithms minimize communication among processors, which allows efficient use of the parallel computer architecture.

TITLE: Graphics Based Control
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed a three-dimensional graphics-based control environment to provide a unique operator interface for the programming and control of complex robotic systems. Sandia has enhanced a commercially available robot simulation, the IGRP^{TM} system, so that as sensors develop additional information about the robot's working environment, the model is dynamically updated and graphically displayed.

TITLE: Grasp Planning
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed a rule-based expert system that generates grasps for arbitrary objects. Input to the system is a symbolic representation of the object to be grasped. This representative may be generated from prestored models. Representation may also be built "on-the-fly" by visual or tactile sensing, or both. The input need not be a complete model of the object.

TITLE: High-Bandwidth In-Contact Robot Control
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Research and development on robot controls is directed at maximizing the bandwidth of in-contact robot control. This work includes research to characterize the torque ripple of robot joint motors for the precise control of joint torques. We are presently investigating the effects of kinematics, dynamics, friction, noise, saturation, and quantization on robot control performance.

TITLE: Hybird Matrix Carbon Fiber Composites
Dr. DeTeresa
Lawrence Livermore National Laboratory, Materials Division/C&MS

This project focuses on developing a dual matrix polymer system to address the manufacturing problem of translating fiber compressive strength to the bulk composite in polymer matrix/carbon fiber systems. One matrix optimized for modules will be utilized within the fiber tow and a second optimized for toughness will be used between the tows.

TITLE: Intelligent Control of Thermal Processes
Dr. Heschel Smartt 202/526-0111
Idaho National Engineering Laboratory

This project addresses intelligent control of thermal processes as applied to materials processing. Intelligent control is defined as the combined application of process modeling, sensing, artificial intelligence, and control theory to process control.

TITLE: Intelligent Process Control of Plutonium Ion Exchange System
John Marinuzzi 505/667-8254
Los Alamos National Laboratory

Neural Networks and other artificial intelligence system are being used to build an "intelligent" automatic process control systems. The AI system presently covers areas of process monitoring, control, inventory control, safety, education and training, and process chemistry.

TITLE: Intelligent Processing
Dr. Herschel Smartt 208/526-8333
Idaho National Engineering Laboratory

1. Intelligent Control of Materials Processes - Research on basic aspects of intelligent control of droplet-based thermal systems. Emphasis is on gas metal arc welding process.
2. Intelligent Control of Nonlinear Processes - Research on fundamental aspects of controlling nonlinear, chaotic processes with emphasis on application of artificial neural networks to prediction and control of model system.
3. Programmable Automated Welding System - Development of intelligent sensors for integration with PAWS system at Babcock & Wilcox Lynchburg, VA.

TITLE: Intelligent Process Monitoring and Control
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed software control technology to facilitate the use of information from a variety of sensors for process monitoring and control. The software architecture is designed to isolate programmers and users from the details of sensor-specific information. The C high-level language allows commercial software libraries to be used for graphical display and data communications.

TITLE: Intelligent System Operating Environment
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed the Intelligent System Operating Environment (ISOE) to support development of intelligent robot systems. ISOE enhances UNIX™ and VxWorks™ operating systems by including the Sandia-developed concept of virtual multichannel communications, which supports the multiple communication channel needs particular to sensor-based robotic systems.

TITLE: Mixed Waste Treatment Project
John Marinuzzi 505/667-8254
Los Alamos National Laboratory

The goal of this project is to develop all intelligent advisory system to aid in decision-making in dealing with the storage, transportation, and treatment of mixed wastes across the nation. Focus of this system is technology definition, schedules and costs.

TITLE: Oscillation Damped Transport
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed control algorithms for oscillation-damped transport of payloads that are supported by cable or are otherwise free to oscillate about the support point. Sandia algorithms control the acceleration of the transporter such that the payload oscillation is damped when the payload arrives as its destination.

TITLE: Precision Automated Turning System (PATS)
Richard Rhorer 505/855-4440
Los Alamos National Laboratory

PATS is part of a DOE/DP process development program to develop precision flexible manufacturing systems (PEMS). The goal of the PATS project is to develop a precision turning system for machining goal spherical parts with minimum of operator intervention of part handling and a minimum of waste. The completed prototype machine will be available about April 1993.

TITLE: Proximity Control for Intelligent Systems
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed software control technology to use range information from proximity sensors for a variety of control applications. This multiprocessor computer architecture allows dedicated sensor processing for proximity-based control functions such as position and orientation control.

TITLE: Resistance Welding Feedback Control
A.E. Bentley 415/294-1375
Sandia National Laboratories, Org. 8484

Feedback controllers are being developed for resistance welding to improve process capability by making highly repeatable welds. This improves quality by reducing variations to very small levels, and also makes the process more efficient by minimizing the need for extensive post weld inspections.

TITLE: Robot Independent Programming Environment
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

The Robot Independent Programming Environment (RIPE) is an object-oriented software architecture developed at Sandia for programming robot systems. RIPE allows for rapid and reliable implementations of complex robot applications by providing a high degree of software reusability, extensibility, and device independence. It provides these features by modeling a robot system.

TITLE: Sensor-Based Payload Docking
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed technology for incorporating noncontact and contact sensing modalities for control of multiple degree-of-freedom robotic system to automatically perform precision docking of large payloads to passive targets.

TITLE: Sensor-Directed, Model-Based Intelligent System Control
Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia's work extends the classical meaning of model-based control to incorporate all available knowledge about the robot and its environment as well as real-time intelligent sensing. The intelligent system controller combines information in the form of CAD, kinematic, and other physical models with sensory information to develop world models to automate robot programming.

TITLE: Torque Control of Robots

Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia is developing torque control technology to achieve two parallel goals. First, overall system safety is improved by reducing damage caused by unexpected collisions of a robot with its environment. Second, torque control improves the backdrivability of systems involved in force contact tasks.

TITLE: Ultrasonic Proximity Sensor Systems

Patrick Eicker 505/844-5827
Sandia National Laboratories, Department 1410

Sandia has developed a versatile multichannel control unit for a VME-standard backplane. This control unit drives and interfaces ultrasonic sensors to VME multiprocessor real-time computers. This system has been used for precision range control of robots, obstacle mapping in unknown environments, and collision avoidance for unmanned vehicles.

AN INTRODUCTION TO INTELLIGENT PROCESSING PROGRAMS DEVELOPED BY THE AIR FORCE MANUFACTURING TECHNOLOGY DIRECTORATE

by

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ABSTRACT

The Air Force Manufacturing Technology Directorate (ManTech) has been promoting and supporting advanced manufacturing initiatives in the area of discrete part manufacturing for many years. The Air Force has numerous on-going manufacturing and integration development programs (Machine tools, Composites, Metals, Assembly and Electronics) which have been instrumental in improving productivity in the aerospace industry, but more importantly, have identified strategies and technologies required for the integration of advanced processing equipment.

This paper provides an introduction to programs in four current ManTech manufacturing thrust areas: 1) Machining Initiatives for Aerospace Subcontractors which provide for advanced technology and innovative manufacturing strategies to increase the capabilities of small shops, 2) innovative approaches to advance machine tool products and manufacturing processes, 3) innovative approaches to advance sensors for process control in machine tools, and finally, 4) efforts currently underway to develop, with the support of industry, the Next Generation Workstation/Machine Controller (Low-End Controller Task).

INTRODUCTION

The Air Force Manufacturing Technology Directorate (ManTech) has long recognized the importance of a strong manufacturing industrial base as being essential for a strong national defense. The Air Force needs advanced weapon systems to accomplish its mission and the production of these systems must be supported by the best manufacturing strategies and processing systems available.

Because the Air Force relies on a strong industrial base, it has sponsored a variety of manufacturing programs throughout its history. A good example is in the area of numerical control (N/C). In 1949 an Air Force contract was awarded to the Massachusetts Institute of Technology which lead to the demonstration of N/C control philosophy. Throughout the 1960's and 70's ManTech sponsored research in areas including the machining of new materials, chemical milling, laser cutting, electrochemical machining and electrical discharge machining. In the late 70's and early 80's research efforts centered on process control and integrated center demonstrations [1]. The integration programs included a sheet metal center, an advanced machining system, and a composite center. Demonstrations for assembly and electronics were also accomplished. These centers have improved productivity in the aerospace industry, but more importantly, have identified the strategies and technologies required for integration.

Until this time, the best technology in the world had been developed and was readily available here, in the United States. The mid-80's found the U.S. machine tool industry rapidly losing its own domestic market share to foreign competition [2]. Because of this trend, President Reagan announced in November 1986 his Domestic Action Plan for the machine tool industry. This plan included the establishment of the National Center for Manufacturing Sciences (NCMS) to help improve manufacturing competitiveness and to create a close link between machine tool builders and the Department of Defense (DoD) Manufacturing Technology program. To kickoff program efforts, a DoD Machine Tool and Manufacturing Technology Development Conference was held in Dayton, Ohio June 1-5, 1987. The purpose of the conference was to support the development of a national program to revitalize the U.S. machine tool industry. Over 350 experts representing a cross section of the industry (machine tool builders, system integrators, control suppliers, academia, government departments, R&D institutions, and manufacturers of discrete parts) attended this conference. The result of the conference was 106 recommendations for further study. Six areas of high priority were defined: controls, information management, sensors, planning and scheduling, standards, and materials/machine design [3]. As a direct result of these six action areas, the Air Force developed four major programs: Machining Initiatives for Aerospace Subcontractors, multiple programs addressing machine tool products and processes, initiatives for machine tool sensor improvements, and the next generation machine and workstation controller (Low-End Controller (LEC) Task).

These four programs address the six priority areas and help satisfy the fundamental needs of the manufacturing industrial base. As an introduction to the technologies that are being developed, the objectives, plans, and expected benefits from some of the programs shall be reviewed.

MACHINING INITIATIVES FOR AEROSPACE SUBCONTRACTORS (MIAS)

The goal of the Machining Initiatives for Aerospace Subcontractors (MIAS) program was to develop and provide advanced technologies and manufacturing strategies to increase the capabilities of small shops. This goal was accomplished by addressing five technology areas that were subcontracted to an experienced commercial team. Overall project management was provided by a systems integrator, Daxus Corp., Pennsylvania. Key areas in the MIAS program include: 1) demonstrations for unattended machining and turning in small shops, 2) development of enabling technologies to help unattended machining become affordable and low risk, 3) software for a flexible Management Planning and Control System (MPCS) for small batch manufacturing, 4) an innovative waterjet process and, 5) a Small Manufacturers' Improvement Service (SMIS) [4].

Two demonstration sites participated in showing the feasibility of using unattended machining in a small shop. The first was a demonstration of unattended milling at Castle Precision Industries, Van Nuys, CA. A machining center with a part queue, a spindle probe, a fixed probe, and torque controlled machining successfully showed that with current technology, small shops can run their machines lightly attended. Similarly, a turning center was demonstrated at Mayday Manufacturing, Lewisville, TX. The turning center has a part handling robot, work queue, turret probe, fixed probe and machining monitor. As a result of these demonstrations, a need was identified for additional technologies before lightly attended or unattended machining could be successful. The areas currently complete are a small footprint work queue, activity fault log, computer assisted programming, tool management, multiple programs per pallet, and a workstation manager [5].

Improved manufacturing is achieved not only through machine improvement, but through improved planning and shop floor control. Solion Systems, now a division of SAIC, has developed a flexible management planning and control system (MPCS) that can be tailored to a specific subcontractor. Six major modules have been developed. Software and documentation is available for quote and order processing, process planning, shop floor control, resource control, production scheduling, and interface to commercial financial packages.

The final area of the MIAS program is the development of an improvement service to assist subcontractors in shop analysis, modernization and strategic planning. Brochures and case studies are available to help shops understand the evaluation process and increase their abilities. Follow-on efforts to the initial SMIS work are currently being explored [6].

Using a structured benefits analysis and validation approach, Price Waterhouse conducted a benefits analysis for the Unattended Turning Workstation (UTW) implemented at MayDay Manufacturing Company, Lewisville, TX and the Unattended Milling Workstation (UMW) implemented at Castle Precision Industries, Van Nuys, CA. This analysis was performed for the period covering September 1987 through March 1991. Quantitative benefits are identified where site data was available. In those instances where benefits will be realized over a number of years, quantitative values are projected. The following identifies some of the key benefits for each site. MayDay should experience: 1) an 18.1% internal rate of return (IRR) projected for the period 1990-1998 given their current business base, 2) a 10% reduction in direct labor costs for the turning function, and 3) an 11.1% reduction in repair and maintenance costs. Castle should experience: 1) a 58.7% IRR projected for the period 1990-1998 given their current business base, 2) a 6.7% reduction in direct labor costs for the milling function, and 3) an 8.7 reduction in repair and maintenance costs. Both sites will experience improved process planning [7]. The MPCS software is currently available and was estimated to have an internal rate of return of 34% as well as provide increased responsiveness and reduced inventory. The SMIS methodologies can be used by organizations for low cost modernization consulting. The overall result is a set of technologies that can be applied to almost any discrete part manufacturer to achieve improvements that will increase competitiveness.

DEVELOPMENT OF ADVANCED MACHINE TOOL PRODUCTS AND PROCESSES

The following programs were awarded as part of a ManTech thrust aimed at developing new machine tool products and processes. The goal is to investigate and develop innovative approaches to advance machine tool products and the manufacturing activities employed to produce machine tools. Ten types of programs are underway or have been completed. The end objective of each effort is to enable domestic machine tool builders to successfully compete with non-domestic suppliers in terms of product performance, quality, reliability, and cost. Five of these programs are briefly described:

Development of New Techniques for Enhancing the Performance of Coordinate Measuring Machines (CMMs)

The new technologies developed under this program include: 1) techniques for on-line simultaneous measurement of geometric errors in components, 2) a retrofitable error compensation technique to improve accuracy of existing, electronically pre-compensated CMMs, and 3) on-line error compensation methods for the enhancement of CMM accuracy at greatly increased throughput.

Coordinate measuring machines and machine tools have historically required increasingly higher accuracies due to the demand for a quality product. This program will use the research experience of the University of Michigan and industrial experience from Sheffield Measurement of Dayton, Ohio, to address the issues of on-line measurement of geometric errors, error compensation for increased accuracy, and retrofit of existing CMMs. Conceptually the design shall use a laser optical system for simultaneous measurement of geometric errors. In the University's previous work, the system has been shown to measure up to five error components per moving axis [8]. The first half of the program included building a prototype, demonstrating a Multiple Degree of Freedom Measurement (MDFM) system on a CMM, and showing feasibility for retrofitting existing machines. The second half of the program currently underway will complete the hardware and software necessary for a retrofit package, demonstrate the retrofit, and assess commercial feasibility.

The MDFM system was implemented on a Sheffield CORDAX RS-30 DCC coordinate measuring machine and was compared to the state of the art Hewlett Packard 5528A interferometer laser system by measuring CMM geometric errors. The MDFM system has measurement accuracy of better than 1μm for straightness and 0.5 arcsec for pitch and yaw.

Increasing Machine Tool Productivity with High Pressure Cryogenic Coolant Flow

The Institute of Advanced Manufacturing Sciences, Inc. has validated a new high pressure cryogenic machining technology. High-pressure cutting fluid applied directly to the cutting edge of the tool has tremendous industrial potential for chip control, increased metal removal rates, increased tool life, and improved surface finishes. This program not only verified the process works, but quantified its economic benefits under a variety of machining conditions. The results provide prospective users of the process with independent data on which to base implementation decisions.

High pressure cutting fluid applied directly to the cutting edge of the tool has usually provided a benefit to most machining operations over normal flood delivery. The use of ultra-high coolant pressure (5,000 psi or greater) directed on the rake side of the cutting edge of an indexable turning insert delivered virtually complete chip control to the turning operation, regardless of the alloy machined. The blending of liquid carbon dioxide with the normal water base cutting fluid takes place at the rakeface and provided a cryogenic mixture of liquid and gas delivered at high velocity to the cutting edge. The low temperature high energy jet of cutting fluid and gas not only broke the chips into small manageable curls, but removed significant amounts of heat from the cutting zone. Thus, the process has improved chip control, increased metal removal rates, increased tool life, and improved surface finish [9].

The benefits of this technology have been documented in the turning of several ferrous and non-ferrous alloys. The improvements in tool life and metal removal rates over normal flood coolant applications were quantified using a standard format of tool life curves, bar charts, and data tables. Differences in chip formation obtained with the low coolant delivery system were also recorded.

Signature Analysis For Forming Processes

Process monitoring is a key component in reducing costs and improving part quality. Industrial Technology Institute, Ann Arbor, MI, has developed a cost effective, state-of-the-art signature analysis system for monitoring forming processes such as stamping and forging. The objective of this program was to develop the prototype of a product that would provide users and vendors of metal forming equipment the ability to automatically monitor forming processes.

This project attempted to apply signature analysis to defect identification in metal forming manufacturing. Signature Analysis applies statistical pattern recognition techniques to the dynamic force measurements of metal forming operations. Instances of both good parts and known defects are collected as training sets. Process defects caused by chipped punches, press stroke changes, and material changes are evident in dynamic force traces. The signature analysis system learns the relationship between the selected features and the existing defect. This relationship can then be used to test for the existence of defects in future process operations.

The learning process for each defect requires a great deal of overhead effort. It would be much more practical to reuse the learning associated with standard die components. For example, a 6-mm punch could be instrumented and the sensor's response to breaking, chipping, and wear could be learned. Anytime this type of punch was used, the learning could be directly reused. This smart punch then would perform metal forming process operations and indicate its own defects. The signature analysis system developed in the project would be a useful tool in the creation of intelligent die components.

Signature analysis works, but the sensor signal must contain the information about the existence of the defect. Signature analysis provides a way of decoding the information from a process signal provided that the information-to-noise ratio of the signal is large enough. This project effort was severely limited by sensor signals that did not respond to the existence of defects. Additional sensor development is needed before signature analysis can be applied effectively in stamping operations [10].

Ultrasonic Finishing System

Extrude Hone of Irwin, Pennsylvania has designed, optimized, and demonstrated a process for the automatic surface finishing of complex shapes. The objective of the project was to develop a new method for finishing the surfaces and edges of complex, high precision cavities by ultrasonic abrasion using a self-forming abradable tool. It established prototype hardware and control software for automatic, close tolerance finishing of complex surfaces. Undesirable surface layer removal, surface roughness improvement, and the edge finishing of complex components were achieved using the ultrasonic machining techniques. The process used high frequency (ultrasonic) vibrations of an abradable tool (which automatically conforms to the work piece) and an abrasive slurry to finish surfaces and edges of complex, highly detailed, close tolerance cavities.

Typical surface improvements range from 5:1 to 10:1; finishes as low as 4 µin R_a can be achieved [11]. A variety of materials including tool steels, carbides, and even ceramics can be successfully processed. Since the tool is not preshaped, but conforms to the workpiece configuration, indexing and registration of the tool and workpiece are not required. Ultrasonic finishing offers a number of important benefits including: 1) specially preshaped tools are not required, 2) precision alignment of the polishing tool to the workpiece is not required, 3) material removal is uniform, 4) surface improvement is 3:1 on machined, EDM'd and cast surfaces, 5) edges can be deburred and lightly radiused, and finally, 6) special operator skills are not required.

Ultrasonic Sensing for In-Process Control of Turning

The work performed by Mechanical Technology Inc. (MTI) and its subcontractors, Pratt and Whitney, United Technologies Research Center (P&W/UTRC), and Cincinnati Milacron Inc. (CMI), developed an in-process control system for turning operations based on the use of an ultrasonic sensor. Ultrasonic sensing will determine the dimensions of turned parts by coupling the part to the sensor by using the ordinary cutting fluid stream while the part is being machined. By analyzing the ultrasonic waves returned from the part, the diameter and wall thickness are determined. CMI also addressed some of the open architecture issues involved in the interconnection of a third-party subsystem with a standard machine tool controller and laid the groundwork for further development of sensor fusion technology.

The velocity of sound in the material is a critical factor in determining the measurement performance that can be achieved. For materials with fixed, known velocities, repeatabilities and accuracies of 0.0001 to 0.0004 in. can be achieved. If the velocity of sound in a material is uniform, such as in alloy steel, wall thickness from 0.075 to 3 in. for parts with IDs greater than 1 in. can be measured with a repeatability in the measurements of ±0.0001 inches. The accuracy of the measurement varies with wall thickness. For steel specimens, an accuracy of ±0.0003 in. was achieved. For aluminum, the accuracy of measurement was ±0.0004 inch [12]. For materials where the velocity varies from batch to batch or within the same specimen (e.g., due to internal stresses or varying hardness), the performance can degrade by an order of magnitude.

The potential for the ultrasonic sensor system is great; it can be used in a wet environment and it has four sensing modes with many applications. The combination of look-ahead and feedback in-process control offers the potential for productivity and quality improvements in a variety of industries. The ultrasonic sensor is an ideal device for providing the measurements to drive these systems. A single sensing element can measure wall thickness and surface finish and can inspect for flaws; a pair of sensing elements can differentially measure ODs and IDs. However, a number of tasks remain to be accomplished to optimize the system.

DEVELOPMENT OF ADVANCED SENSORS FOR THE PROCESS CONTROL OF MACHINE TOOLS

The following programs were awarded as part of a ManTech thrust aimed at developing sensor technology for process control on machine tools. Six types of programs are underway. The end objective of each effort is to enable domestic machine tool builders to successfully compete with non-domestic suppliers in terms of product performance, quality, reliability, and cost. Four of these programs are briefly described:

Non-Contact Laser Profile Gage

Chesapeake Laser Systems and their subcontractors, Cincinnati Milacron and Rockwell International, will establish an engineering prototype of a new machine tool feature to enable effective on-machine, non-contact inspection of complex and contoured parts. Chesapeake's non-contact scanning laser gage will use one or more solid-state laser sensors designed to conform to task requirements for range, standoff, resolution, speed and environmental factors.

Real Time Tool Condition Monitoring

FASTMAN, Inc and their subcontractors, University of Minnesota, Ingersall-Rand, and General Motors, will develop, test and commercialize the Intelligent Insert, a low-cost tool condition monitoring system for CNC turning centers. The Intelligent Insert will monitor tool condition by simultaneously sensing ultrasonic acoustic emission signals and vibration signals. The Intelligent Insert is a thin-film transducer deposited directly on the cutting element of a machine tool. The sensor construction technique automatically provides an acoustic bond and the result is a highly sensitive transducer with a large bandwidth. The addition of high speed electronic systems for signal conditioning and filtering leads to an effective and inexpensive tool condition monitoring system. This technology offers a reliable approach to tool condition monitoring and has been verified by tests conducted at the University of Minnesota.

Tri-Beam Gage Turning Center

Industrial Technology Institute and their subcontractors, Air Gage Company, Saginaw Machine, and General Motors, will build and test a prototype of the tri-beam gage for use in monitoring turned parts. The tri-beam gage works on the same principle as the standard v-block gage; it is simply the optical equivalent. In the place of the vertex mounted micrometer, ITI uses a sheet of light and a detector array similar to that used by commercial laser micrometers. The advantages of the tri-beam gage include: 1) calibration independent of machine tool scales, 2) non-contact, damage-free operation, 3) high speed, and 4) the ability to measure parts in motion.

Sensors for Cutting Performance of Machining Centers

Manufacturing Laboratories, Inc. and their subcontractor, Automation Intelligence, will develop a milling machine system that will detect chatter or tool breakage and feed necessary information to the controller for closed-loop process control. An NC program will be able to detect a feature that is limiting or spoiling the proper milling operation, provide an action to eliminate the disturbance immediately, and then proceed in an improved way. When made, some of the corrections (like new spindle speeds or reduced depths of cut) will be embedded in the NC program to be used for future repetitions of the particular operation. The resulting product is a self-contained unit, which is easily interfaced with any machine tool. It is especially suitable for retrofits.

THE NEXT GENERATION WORKSTATION/MACHINE CONTROLLER PROGRAM (NGC) - LOW-END CONTROLLER (LEC) TASK

The NGC program will develop and validate the Specification for an Open System Architecture Standard (SOSAS) developed under the NGC program. It will govern the design and construction of a family of workstation and machine controllers that will be competitive with the features and performance of commercially available controllers. The SOSAS will consist of the NGC System Specification, NGC Subsystem Specification, NGC Module Specification, and Neutral Manufacturing Language (NML). The program will also identify and demonstrate new technologies and strategies required to support an increase in the controller's capability, reliability, and performance while supporting a decrease in cost. The SOSAS will enable competing vendors, integrators and users to use available modules of the NGC family, while permitting specialization by companies or designers during module development.

The NGC will consist of subsystems containing functional modules interconnected by standard interfaces. The modules may be assembled in a variety of configurations to provide subsystems for a wide range of machines and workstations. The NGC architecture will support a wide range of processing and discrete part manufacturing applications including machine tools, robots, electronic assembly devices, material handling devices, inspection devices and virtually all types of automated equipment in manned or unmanned, networked or stand-alone environments [13].

The NGC will provide control for the manufacturing workstation and its subsystems. A Workstation consists of a single material transforming device and its related supporting equipment (such as material handling or inspection), with enough information processing and control to permit independent response to commands.

During the program, industry participants will plan for the first validation of the SOSAS by building and testing a LEC (two axis motion control). The LEC will be demonstrated at IMTS 1992. The participants will test the product developed to ensure compatibility with other NGC modules and with products that comply with the SOSAS. Before the completion of NGC activities, the project team will document the conformance testing on additional processing systems and will develop plans for specification support following government participation.

The NGC will require a variety of improvements over both current and future controllers to truly be "next generation." These improvement strategies will include an open architecture, the workstation controller with PDES input, and a neutral manufacturing language. By initiating the NGC program, the Air Force plans to revitalize the domestic controller industry by bringing vendor, integrator, and user together in a cooperative effort [14].

SUMMARY

The Air Force will continue to build upon a solid history of research and development in the manufacturing and machine tool industry. The initiatives discussed in this paper are representative of numerous programs that have made or will make constructive impacts upon the manufacturing industrial base. Because of the strategic importance of a strong industrial base, the continued health of the domestic machine tool industry will continue to be a priority for the Air Force.

The MIAS program was an attempt to completely automate small shop operations. With the assistance of enabling technologies, new processes, products and sensors will make intelligent processing affordable and low risk. Finally, the NGC will take the next step of integrating these systems into a single intelligent controller. The information and technology developed by these programs will improve shop performance; however, it is the integration of the technologies that will bring manufacturing into the next century.

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ARMY (MANTECH) THRUST AREA CONCEPT - OPTICS THRUST AREA

by

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ABSTRACT

With the shrinking of the U.S. Army's material needs and the compression of defense requirements, the Army Manufacturing Technology (MANTECH) Program has the opportunity to advance manufacturing state-of-the-art and solve near team production problems of the U.S. Industrial Base. To exploit this opportunity the Army restructured its MANTECH efforts in FY90 based on a thrust area concept. Each of the ten current thrusts, directed by a thrust area manager, has a broad technical objective selected to improve specific manufacturing processes. The manager is charged with setting objectives, selecting tasks, monitoring execution, leveraging external resources and establishing microfactories to promote technology transfer. The Optics Manufacturing Thrust is an example of the concept. It is currently directed at revitalizing the domestic precision optics manufacturing base, now characterized by high labor costs and 1940's technology, through introduction of revolutionary machines, new processes and CIM principles. Leveraging of MANTECH dollars with those of industry, academia and state governments led to the establishment of the Center for Optics Manufacturing and plans for regional centers. Recognition of the U.S. as a world leader in precision optics manufacturing and a dramatic reduction of both manufacturing time and cost should accrue from thrust area efforts.

INTRODUCTION

This paper will present an overview of the U.S. Army's Manufacturing Technology (MANTECH) Program objectives and strategy in meeting the challenges in manufacturing brought about shrinking defense needs and procurements. Until FY90 the Army MANTECH program consisted of a large number of projects each directed towards a single issue. In FY90 the Army in order to better manage its limited resources in the manufacturing technology arena, decided to focus its efforts into thrust areas which would consist of groups of projects related to a particular technology with high importance to the Army's mission needs. One particular thrust area established was in optics manufacturing. This area, which is endeavoring through technology to revitalize a dwindling domestic precision optics production base, serves as example of how the thrust area concept functions.

ARMY MANTECH PROGRAM

MANTECH Challenges:

The current status and future direction of the Army MANTECH Program has been shaped by significant decisions by both U.S. Army management and the Congress. Over the last three to five years, the productivity of the U.S. Industrial Base has been called into question in terms of its competitiveness with other nations in the Pacific rim and Europe. Several studies have been conducted which highlighted the problems which make the U.S. less competitive.

Although a steep decline in total Army funding is projected and an overall reduction in size is being planned, the Army still expects to spend in excess of $10 billion a year on systems and equipment. Size reduction implies lower quantities which in turn, using standard economics of quantity versus price, implies higher unit costs. This, coupled with the impact of increased manufacturing criteria to achieve higher weapon system performance as a result of the lessons learned from Operation Desert Storm, will tend to drive the cost of components and systems even higher. It is therefore essential that a concentrated effort be made to reduce each of the three elements effecting unit cost: investment, direct and indirect costs. The Army MANTECH program must promote flexible manufacturing systems that can produce both military and commercial products and drive the design of weapon systems so that they can be manufactured using general purpose tooling as ways of reducing capital investment costs. Direct costs must be address by MANTECH through new or improved manufacturing processes, reduction of waste, scrap or rework, and improved overall process control to reduce required inspection. Design for manufacturing in a concurrent engineering environment, worker training, environmental hazard reduction, and computer integration of management and process control data are areas for concentration for MANTECH to address indirect costs.

The MANTECH Program is concentrating on the new or improved processes that have broad applications which transcend any individual weapon system. In this role it serves as a partner in the overall Army Manufacturing Technology with the 6.1 - 6.3a technology base efforts aimed at developing manufacturing processes with emerging technologies and with system development programs where specific production processes development and planning is funded.

Strategy and Objectives:

The U.S. Army's strategy in the area of manufacturing technology is to support U.S. Army acquisition, exploit emerging advanced technology, promote technology transfer to the industrial base, and leverage U.S. Army resources through cooperation and coordination with other Department of Defense components, industry and academia.

The Objectives of the Army MANTECH Program are to advance the state-of-the-art in manufacturing, improve end item quality,increase process control and repeatability, enhance worker and environmental safety, and promote competitiveness of the U.S. Industrial Base. Achievement of these objectives will ensure a reduction in the variability of products and the cost of production and ownership.

Thrust Area Concept:

The Army MANTECH Program was restructured starting in FY90 based on a thrust area concept. A thrust area consists of a broad technical objective selected to improve specific manufacturing processes and is presided over by a thrust area manager. These thrust area managers are responsible for setting technical objectives, collecting task ideas from throughout the Army, establishing task funding priorities, monitoring program execution, and serving as the focal point for the thrust area's technology transfer.

A second aspect of the thrust area concept is the leveraging of Army resources. One criteria for selection of thrust areas was the potential for success in bringing in partners from industry, academia, or other government agencies to contribute resources and ideas in order to promote the technology and implement the results.

The third aspect of the thrust area concept is the establishment of a physical focal point for the technology in a microfactory. Some thrust areas may have more than one microfactory, but the goal is to have a location where government and industry can come to look at new machine systems or processes, conduct hands on experimentation, acquire training, develop ideas on how the technology can be applied, and ultimately implement the machine, system or process into their own manufacturing site.

In FY91, the U.S. Army was managing 11 thrust areas. One of these is for single issue tasks which are those tasks that are not part of any one thrust area but offer significant opportunities to the Army or are the initial tasks to get a new thrust area started. The remaining ten thrust areas are:

- Composites/Adhesive Bonding
- Energetic Materials
- Electronics Manufacturing Process Control
- Night Vision/Electro-Optics (NV/EO)

- Environmentally Acceptable Materials, Treatments and Processes
- Missile Seekers
- Advanced Non-Destructive Evaluation and Sensors In Manufacturing (NDE/SIM)
- Chemical Defense Manufacturing
- Optics Manufacturing
- Soldering Technology

OPTICS THRUST PROGRAM

Introduction:

An example of the Army's thrust area concept is the Optics Manufacturing Thrust. Optics are a key supporting technology in several Army systems and recently in Operation Desert Storm demonstrated their strategic benefit: tank Gunner's and tank Commander's sights, laser target designators and rangefinders, and, most notable, the night vision capability of several systems allowed U.S. forces, through the use of optics, to identify and neutralize Iraqi positions long before they were a threat.

A Joint Logistics Commanders study, completed in 1987 and chaired by the Army, assessed the state of optics manufacturing in the U.S. The results of that study showed the domestic optics industry was in serious decline and a serious shortfall existed in mobilization capacity. While the demand for optics have remained constant or increased, domestic optics sales have decreased to the point where the industry has reduced its labor force by over 50%. Other studies have indicated that 97% of all commercial optics and probably more than 75% of military optics are imported. The problem is centered around the fact that the optics industry worldwide is using 50 year old technology with labor intensive processes and operations requiring high skill levels. In labor intensive manufacturing the lower cost wage structures of developing countries will always come out on top in a competitive environment. Other contributors to the overall problem are: a major decline in technology investment; use of "black art" processes and methods; increased management to direct labor cost; off-line and after the fact quality inspection; and the non-availability of statistical process control and computer integrated manufacturing techniques.

The Army MANTECH Optics Thrust was initiated in FY89 to address this industry decline and insure a quick reacting domestic mobility base. The Optics thrust has as its objectives to provide flexible manufacture of visible, near- and far-infrared optics, to introduce and establish computer integrated manufacture (CIM) to the optics industry and to establish CALS compatibility for both prime and subtier optics manufacturers. Expected benefits of the thrust effort, in addition to reversing the industry decline and improving mobilization, are a 40% reduction in optics manufacturing costs yielding an estimated savings over 10 years of 100 million dollars.

Thrust Area Technology Efforts:

Current efforts being conducted under the thrust area include machine and tooling development, process development and introduction of computer-aided manufacturing CIM principles to the optics industry.

In the area of machine development it was decided that new, revolutionary machines with performance capabilities heretofore unknown in optics manufacturing were required to reduce both the processing time and cost of producing an optical component. Under computer control, these machines, which are affordable to even the smallest manufacturer since they replace several existing machines, will reduce the number of manufacturing steps through multiple grinding/centering operations, on-machine inspection and in-process correction.

A family of four (possibly five) OPTICAM (optics automation and management) machines are to be developed. The four correspond to the major categories of optical components, namely, spherical (lenses), prisms, plano (flat surface) and aspheric. The fifth machine, if needed, would provide final polishing of components. Two machines, the spherical (SM) and prism (PM) modules, are currently under development with early and mid 1992 deliveries, respectively. Development of the remaining two machines will begin in FY93. Both the machines possess stability, mechanical tolerances, and operational speeds which far exceed the best machines currently available.

To support the OPTICAM machine, grinding and polishing tools, a common tool for holding the workpiece and method to hold the workpiece to the tool had to be developed. In addition to the design of a quick connect/disconnect common tool configuration, a major development to date has been the definition of an adhesive to hold the workpiece in place during manufacture. This strong, no-residue adhesive will of itself significantly change even the current manufacturing process.

The optics industry currently relies on the skills and intuition of skilled opticians to define the optical manufacturing process for a particular facility. Automating the machinery for manufacture is not conducive to these processes. Deterministic processes governing the fabrication of particular materials must be available and understood for the advantages offered by the new machines to be realized. Process experiments are underway to determine correlations between process parameters and resulting surface quality and extent of sub-surface damage. Experiments have succeeded in identifying several such correlations for five different common glass types. Work is continuing to expand the experiments to study additional parameters and to encompass all glass types commonly used in the optics industry.

The introduction of Computer Integrated Manufacturing (CIM) to the optics industry and the application of concurrent engineering principles is critical to continued viability of the domestic optics industry. The OPTICAM CIM effort is aimed at providing a link all aspects of the optics industry from design through fabrication and includes the establishment of a manufacturing data base and business operations such as estimating and inventory. Simulations have been established and two actual CIM demonstration systems compatible with small and large optics production facilities will be operational in FY92.

Future efforts will involve the development of the plano machine and more significantly the asphere machine which could revolutionize optical system design in that it offers the potential to make heretofore difficult to manufacture components both available and affordable. Metrology techniques to support on-machine inspection will be developed. Extension of process and inspection technology from the current emphasis on glass to infrared optical materials will take place.

Leveraging of Resources:

One of the significant offsprings of the Optics Thrust efforts has been the support provided by the industry through the American Precision Optics Manufacturing Association (APOMA). APOMA, with over 80 industry and academia members, represents a new area of cooperation in an industry previously regarded as secretive and extremely protective of its individual processes. The level of support is such that over $14 million has been pledged ($3.8 million already received) in the form of cash, donated labor, equipment and facilities by industry and academia to support the development of OPTICAM. These pledges are essentially equal to the planned Army Optics Thrust funding over the next five years.

Center For Optics Manufacturing - Microfactory:

As a consequence of Army MANTECH funding, the Center For Optics Manufacturing (COM) was established by APOMA at the University of Rochester, NY. Currently housed in a temporary facility the COM will move into a new 30,000 square foot facility now under construction in late FY92. This facility will not only serve as a microfactory to demonstrate the newly developed machine, process and CIM technologies but as a training and resource center and a repository for an industry accessible manufacturing data base. In order to better serve the optics industry nationwide, two satellite centers will be established in California and Florida with training and demonstration capabilities similar, albeit smaller, to that found at Rochester. These centers will facilitate the implementation of the newly developed manufacturing technologies.

Conclusion:

Since its formal beginnings in FY90 the Optics Thrust has developed into a prototype for the Army MANTECH Thrust Area Concept by successfully: focusing on a specific technology area critical to the Army mission and mobilization base; forming an industry, academia, and government partnership with significant leveraging of Army funds; and the establishment of the Center For Optics Manufacturing as a microfactory and implementation mechanism.

INTELLIGENT PROCESSING EQUIPMENT DEVELOPMENTS WITHIN THE NAVY'S MANUFACTURING TECHNOLOGY CENTERS OF EXCELLENCE

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ABSTRACT

The U.S. Navy has had an active Manufacturing Technology (MANTECH) Program aimed at developing advanced production processes and equipment since the late-1960's. During the past decade, however, the resources of the MANTECH program have been increasingly concentrated in "Centers of Excellence" as such centers have proven their worth. Today, the Navy sponsors four manufacturing technology Centers of Excellence: the Automated Manufacturing Research Facility (AMRF); the Electronics Manufacturing Productivity Facility (EMPF); the National Center for Excellence in Metalworking Technology (NCEMT); and the Center of Excellence for Composites Manufacturing Technology (CECMT). This paper briefly describes each of the centers and summarizes typical Intelligent Equipment Processing (IEP) projects that have been undertaken by each.

INTRODUCTION

The Navy has been actively involved in the development of new and improved manufacturing processes and equipment under its MANTECH Program since 1968. The MANTECH Program plays a key role in attacking the problems of productivity and competitiveness. In the past, the program has covered almost all types of manufacturing technology and has supported the full range of weapon systems developed by the Navy, including ships, aircraft, munitions and missiles.

Historically, the MANTECH Program consisted mainly of individual projects that were conceived, executed, implemented and managed as separate entities. As such, there was little synergism between projects, in terms of either technical content or the cumulative expertise that comes from execution of the effort.

During the past decade, a new concept has evolved, namely that of "centers of excellence," that would overcome some of the difficulties of executing the projects as separate entities. As the name implies, a center of excellence is a recognized focal point for development and dissemination of technology in a specific field. As used here, however, the concept of a center of excellence has several other implications. In addition to providing a centralized source of technical expertise, the center also serves as a means of bringing together government, industry and academia to focus on critical areas of development, for both technical and financial cooperation.

The Centers of Excellence concept has proven to be highly successful. Since the introduction of the first Navy Center of Excellence nearly a decade ago, the number of centers has grown to four which cover automation, electronics manufacturing, metalworking and composites. Today, a significant portion of the Navy's MT Program funds are directed to Centers of Excellence, and this trend is expected to continue in the future.

Although the Navy Centers of Excellence share a common objective and approach, they also differ considerably in terms of their organizations, sponsors, operating strategies, levels of industry involvement and means of technology transfer.

Each of the centers is briefly described in the following sections.

AUTOMATED MANUFACTURING RESEARCH FACILITY

The Automated Manufacturing Research Facility was created at the National Institute of Standards and Technology (NIST) in 1981. The AMRF is a major national laboratory for technical work related to interfaces and standards for the next generation of computer-automated manufacturing. Since 1983, the AMRF has been jointly sponsored by the Navy. The facility was put into full operation in 1986. A companion installation, located in an adjacent shop, serves as a state-of-the-art production facility, making use of the best commercially available technology. In addition to the Navy and other government agency funding, private firms and universities also contribute to AMRF research through the donation or loan of equipment or by providing personnel through the NIST Research Associate and Faculty Participation Programs.

The AMRF is a research testbed. Equipment includes computer numerically controlled machine tools and a variety of industrial robots to tend the machine tools and do specialized tasks. Manufacturing tasks are performed by groups of equipment components, called workstations. Each workstation has an internal hierarchical control structure. The cooperative actions of all the workstations are also controlled by a higher level process within the hierarchical structure. Each workstation is a component of the integrated factory.

The AMRF facility currently supports a wide range of research in machine tool and robot metrology, sensors and sensory processes, robot safety, robot control, software accuracy enhancement of machine tools, process planning and data preparation for machine tools and robots, parts routing and handling, real-time control of robots and associated equipment, workstation control, cell control, and materials handling control. The facility is particularly valuable for studying interfaces between control modules and among data users. The AMRF is unique in the opportunities it provides for studies of an integrated systems of significant size.

The facility consists of a two-robot cleaning and deburring workstation, inspection workstation, vertical machining workstation, and two special project areas, which are occupied by applications-oriented projects, several of which are discussed later. Nearby are a manufacturing systems integration (MSI) system and a composites manufacturing workstation. Using the MSI system, researchers continue the study of AMRF control and data architectures, making use of the shop floor facility for validation of simulated results.

Most of the research conducted at the AMRF falls under the category of Intelligent Processing Equipment as used in this conference. Several of these projects are discussed in more detail below.

Real-Time Error Corrector (RTEC)

Correction of a machine tool's tool path, based on the prediction of the geometric and thermal errors, has been accomplished in the laboratory by laboriously modifying the hardware and/or software of the machine tool's CNC controller. However, this type of modification requires detailed knowledge of the existing controller software and hardware and is not suitable for broad commercial application. The lack of a good interfacing technique has been the major obstacle to implementing real-time error compensation of machine tools.

NIST developed the Real-Time Error Corrector (RTEC) to eliminate the machine tool controller interfacing problem. The RTEC is inserted between the machine tool controller and the machine tool's encoder-type position feedback devices. The RTEC is capable of modifying the tool path without any knowledge about the machine tool controller's design. The result is that the machine tool produces higher accuracy parts, even during much of its thermal warm-up period.

Another technique made possible by the RTEC is fast probing. In small batch manufacturing, traditional statistical process control techniques are not sufficient. One method of improving accuracy of parts is to use process-intermittent gauging (i.e., part probing on the machine tool in between machine steps). However, the desire to shorten machining cycle times makes long inspection times unacceptable. Probing cycles currently implemented by machine tool controllers use slow feed rates and are slow in transferring probe data to external computers. Fast part probing using a touch trigger probe, with about one probe trip per second, minimizes the time consumed by the measurement. Fast probing increases the machining productivity of a machine tool when on-machine inspection is performed.

Of course a better way to implement these techniques is through open, publicly documented controller interfaces. NIST is working with members of the Next Generation Controller and low end controller projects to develop such interfaces.

Fastener Workstation

The fabrication of high-tolerance fasteners, such as hex head bolts, screws, and studs, is critical to the maintenance of submarines. With tolerances as small as 12.7 μm, these fasteners often require frequent inspection at various stages of production. In addition, they are typically made in small lots from hard-to-cut materials such as K-monel. These three facts -- tight tolerances, small lots and exotic materials -- along with strict audit trail documentation requirements make these fasteners difficult and costly to procure.

NIST is working with personnel from the Portsmouth Naval Shipyard and several private companies to build an advanced, computer-controlled, machining workstation capable of automatically manufacturing, inspecting, and engraving these fasteners.

The fastener workstation consists of a workstation controller, a turning center with milling capability, a computer-aided-manufacturing (CAM) system and a marking system. The numerical control (NC) programs for the fasteners that are generated from the CAM system can be downloaded from the programmer's office to the workstation controller via fiber-optic link. In addition, the workstation has hardware and control software to inspect the parts during the manufacturing cycle and to permanently mark the finished work pieces. The marking of a lot ID number on each fastener during the manufacturing process will allow the current audit requirements to be followed to the final installation of the fastener.

The integrated workstation maintains a relational database system to support the manufacture of studs, hex head bolts and cap screws in a wide range of sizes, from 1/4 to 1-1/2 inches, as well as the manufacture of other parts of similar geometry.

The hardware and software have been integrated, and certified parts have been produced. Two techniques pioneered at NIST, error compensation and in-process control, are also being incorporated into the workstation. In addition, NIST researchers expect to develop new statistical process control techniques to be used in this and other small batch production environments.

After the workstation is completely developed at NIST, it will be run by the shipyard operator to assure the performance and reliability of the total system. Upon completion of the test run, the entire workstation will be moved to the Portsmouth Naval Shipyard for production use.

Molecular Measuring Machine (M^3)

By the year 2001, uncertainty requirements for dimensional metrology of step heights, surface roughness, linewidths and line spacing for integrated circuits and optics will be 0.1 to 1 nm. Furthermore, these uncertainties must be held over areas ranging from several square millimeters to fractions of a square meter.

To address this need, NIST is building the molecular measuring machine. M^3 will be capable of positioning and measuring to atomic-scale accuracies over an area of 25 square centimeters. It incorporates a scanning tunneling microscope into a unique system design that includes a very stiff core structure, carriages for moving the probe over the sample, interferometry for measuring probe and sample positioning, and two stages of isolation from seismic and acoustic perturbations.

After construction is completed, M^3 will serve as an independent means for characterizing distances, geometries and distortions of highly ordered arrangements of atoms on single-crystal surfaces. M^3 also will serve as an exploratory tool for building mechanical and electrical structures in the nanometer-size range.

Other Intelligent Processing Equipment Projects

The previously mentioned efforts only represent a few of the IPE projects NIST has undertaken at the AMRF. Other examples include:

1. The development of a tool management system for the Army's Rock Island Arsenal.

2. Participation in the development of the Air Force-sponsored Next Generation Controller program.

These are but a few of the examples of NIST research in IPE at the AMRF. However, they do reflect what can be achieved when industry, government and academia work in a cooperative manner in this important field.

ELECTRONICS MANUFACTURING PRODUCTIVITY FACILITY

The EMPF is the second oldest Navy-sponsored center of excellence, having been established in 1984 to help the electronics industry improve manufacturing processes, process controls and materials through research. Initially operated at the Naval Weapons Center in California, the EMPF was moved to Indianapolis in 1990. The EMPF is now operated as a consortium of the Naval Weapons Support Center in Crane, Indiana; the Naval Avionics Center in Indianapolis; and the Indiana University-Purdue University at Indianapolis.

The center is guided by two industry advisory committees: an Executive Advisory Board and an Electronic Equipment Manufacturers Committee. The Executive Advisory Board currently consist of representatives from 16 Fortune 500 defense suppliers. Another ten members representing the consumer and industrial electronics manufacturing sectors are also being added to the board.

The Electronic Equipment Manufacturers Committee is primarily comprised of small and medium process equipment manufacturers that provide over $4 million in equipment and supplies for operation of the EMPF. More importantly, these equipment manufacturers are positioned to commercialize EMPF process developments. If one were to account for all the companies that have contributed resources to the EMPF's operations through the committee, the number would be well over 100.

The EMPF is focused on improving electronics manufacturing processes and deploying these advances to both U.S. defense and commercial electronics suppliers. This deployment is accomplished through a demonstration factory, industry training courses, university education, workshops, seminars, conferences, publishing and licensing.

The ultimate goal of the EMPF is to increase the productivity of electronics manufacturers by providing services that foster technological innovation, capital and human resource investment.

Incorporation of intelligent production process equipment is inherent in developing production processes for higher density electronic packaging. Two of these projects that involve IPE are described below.

Manual Soldering Process Monitoring System (MSPMS)

Hand soldering introduces process parameters which are difficult to control and result in considerable variation in the quality of individual solder joints. Humans simply are not able to repeat operations with the consistency of a machine. To overcome this problem, a method of process control was required for variables such as time-on-connection, tip temperature and amount of heat delivered to the connection. Another reason for developing the MSPMS was because of the trend in defense electronics manufacturing away from 100% inspection of solder joints and toward the use of process controls as a means of improving product quality, which is precisely the rationale behind IPE.

The MSPMS system is a process monitoring and control system for manual soldering. The system includes a microprocessor "tower" for controlling the soldering iron, a digital recorder, an eight channel data acquisition system, and an 80386-based personal computer. (The digital recorder will not be part of the final system; it is currently used to record and simulate the signal from the soldering iron during system development and testing.)

Up to eight soldering irons can be monitored using EMPF custom adaptors and software. The MSPMS provides an environment for data collection, calibration, analysis, printing, viewing, and graphing of solder iron tip temperature data. Interpretation of this data by an operator's supervisor will identify the need for training, because of operator inconsistencies, or repair, calibration or replacement of degraded equipment.

The system collects real-time power readings for the soldering irons. The power is translated into a predicted tip temperature via EMPF developed algorithms based on heat transfer theory and soldering tip configurations. An analysis program characterizes temperature changes over time as soldering, cleaning, transport or convection phenomena. Computations are provided for time-on-connection, tip temperature and the amount of heat delivered to connections.

Development of the MSPMS was initiated in 1988, and Beta site testing in a production environment should begin next year. EMPF has a goal to have the MSPMS become a commercial product by 1993.

Solder Technology Microfactory

In June 1991, the U.S. Army and EMPF formed a strategic alliance for the purpose of promoting the knowledge base in soldering sciences that was developed under the Army's MANTECH Program at Harry Diamond Laboratories. The partnership established a microfactory at EMPF to demonstrate process control and machine artificial intelligence. Core equipment includes an X-ray laminography system and laser imaging machines capable of creating 3-D models of solder joints and components.

Building on previous modeling work performed at NIST, models will be enhanced at Purdue University in Indianapolis. Faculty and graduate students will be able to correlate inspection characteristics with failure mechanisms. This will provide a foundation to investigate and demonstrate real-time process controls and for predicting product reliability improvements based on design and material modifications.

The relatively new microfactory has several potential outcomes, including:

1. Artificial intelligence based process control that accounts for real-time finite element analysis of solder joints and correlation to failure mechanisms.

2. Characterization of new materials able to increase the reliability of solder joints, components and electronic assemblies.

The Solder Technology Microfactory should prove to be a unique collection of equipment and expertise necessary to understand solder science and solder material characteristics for the purpose of improving the reliability of interconnect technologies through scientific understanding of the principles involved.

NATIONAL CENTER FOR EXCELLENCE IN METALWORKING TECHNOLOGY

The NCEMT was established in 1988 under the Navy's MANTECH Program to address Navy and Department of Defense metalworking technology needs. NCEMT serves as a national resource for the development and dissemination of advanced metalworking technology and processes to improve the defense industrial base. The center is operated by Metalworking Technology, Inc., a nonprofit subsidiary of the University of Pittsburgh Trust. From an initial staff of 25 in 1988, the NCEMT has grown to 145 materials scientists, engineers, technicians and support personnel.

Leading edge technologies, such as process modeling, expert systems, and state-of-the-art test equipment, are being emphasized at the NCEMT to ensure that effective, long-term solutions to metalworking problems are being addressed. NCEMT's focus is on high risk/high impact metalworking problem areas involving both traditional and advanced materials.

As with the other Navy centers of excellence, the NCEMT is deeply involved in projects that relate to IPE. A few of these efforts are briefly described below.

Plasma Spray/CNC Workcell

The objective of this project is to integrate plasma spray process technology and CNC technologies into an automated system for repair and maintenance of metal parts. The workcell will contain integrated parts preparation, thermal spraying, parts finishing and quality assurance modules.

Casting Technology Development

The objectives of this process are to improve defect management (i.e., prediction and control) in castings and to optimize tooling design (e.g., risers, gating, etc.). IPE is a key element of the process because of the benefits that can be obtained through the use of intelligent processing. In addition, the Rational Process Design methodology is being followed to meet process objectives.

Optimized Weldment Properties

NCEMT and the Navy's David Taylor Research Center have a cooperative project to develop and demonstrate the technology that will allow for the use of optimized weld metal properties, especially yield strength, required for improved productivity, cost reduction, and structural integrity of high strength steel pressure hull structures. As part of this program, an optimized welding system utilizing IPE concepts will be identified and assessed from the standpoint of productivity improvement and cost savings potential.

CENTER OF EXCELLENCE FOR COMPOSITES MANUFACTURING TECHNOLOGY

Established in June 1990, the CECMT is the newest Navy Center of Excellence. As the name implies, the CECMT will provide a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors, and as a means for applying this technology to the solution of Navy and DoD technical and productivity problems in composites. The CECMT is operated by the Great Lakes Composites Consortium, a not-for-profit organization located in Kenosha, Wisconsin. The consortium's members include a number of manufacturing, engineering, research and academic organizations interested in advancing composites manufacturing technology.

As the performance requirements of systems and components continue to increase, traditional engineering materials are not always able to meet the requirements. Composites are playing an increasing role in meeting the needs for advanced engineering materials. However, the manufacture of composite components is in an early stage of development compared to metals, and very little is known about detecting and repairing damage in composite structures. The CECMT will play a key role in addressing these issues.

Being the newest center, the CECMT's projects are not as far along as those of the other centers. However, the CECMT does have a number of programs underway that encompass IPE concepts. For example, the CECMT is pursuing research in such areas as resin transfer molding, fit-up of composites structures, powder fusion coatings, and composite repairs, each of which will involve some level of intelligent process. In addition, the CECMT is establishing a Composites Manufacturing Technology Teaching Factory that will include IPE in its workstations.

While these efforts are getting under way, the CECMT is also in the process of forging linkages with other organizations that are interested in developing or using composites manufacturing technology, much of which will rely on IPE to achieve the necessary product quality, low costs and reduced leadtimes in order to compete effectively in world markets.

INTELLIGENT PROCESSING EQUIPMENT PROJECTS AT DLA

by

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ABSTRACT

The Defense Logistics Agency is successfully incorporating Intelligent Processing Equipment (IPE) into each of its Manufacturing Technology thrust areas. This paper addresses several IPE applications in the manufacturing of two "soldier support" items; combat rations and military apparel. In combat rations, in-line sensors for food processing are being developed or modified from other industries. In addition, many process controls are being automated to achieve better quality and to gain higher user (soldier) acceptance. IPE applications in military apparel include: in-process quality controls for identification of sewing defects, utilization of robots in the manufacture of shirt collars, and automated handling of garments for pressing.

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD) PROGRAM

Methods and equipment used by current producers of military unique combat rations are very labor intensive. New process technology in packaged food products is necessary to improve quality, shelf life (which is essential to combat rations), and user acceptance.

DLA has established a cost sharing contract with Rutgers University to address problems in the packaged food industry. The specific objectives are to develop new food processing methods and equipment for combat rations with the flexibility to produce commercial products. Rutgers is working with a coalition from industry that includes food processors and food processing machinery manufacturers, some of whom are already using advanced sensors and process controls.

Intelligent Processing Equipment in the Manufacturing Technology Program (MTP) to Improve Combat Ration Production Processes

One objective of the program is to identify the food product characteristics and parameters that need to be controlled because they influence final product quality and user acceptance. Rutgers is well equipped and capable of conducting experiments in rheology, mass spectrometry, spectroscopy and calorimetry, and had previously sponsored workshops in robotics as applied to handling placeable food items. In the **"Generic Process-Quality Control Systems"** project, bench top and short run experiments have been designed and are being conducted to optimize on the yield of beef used in combat rations, which is an expensive ingredient. Yield is influenced by heat applied during thawing (if frozen), pre-cooking, and sterilizing in the retort. The viscosity of gravy is influenced by the pre-cooking treatment of the beef, as well as the water content of other ingredients, but can be adjusted if other variables are known. Sensors for temperature and pressure that can be used in the process equipment during these preparation stages without deterioration are being developed.

Improved controls are being introduced to processing equipment such as cookers, ovens, and retort sterilizers to achieve optimum food preparation and sterilization, and to avoid over processing, which leads to reduced acceptability by the user. Several new sensors and mechanisms capable of detecting temperature, pressure, pH, and viscosity on line need to be integrated into a control system to be useful. The short term project **"Architecture for Packaged Food Processing"** is focused on identifying and integrating control data from all of the information detectors into a computerized process control system. As a result of these efforts, rapid sensing, monitoring and testing methods and process controls will be introduced to minimize process variations.

Intelligent and programmable processing equipment such as fiber optics, robots with sensors and machine vision, and electronic controls have potential application and are being developed. Two projects in this area are **"Package Integrity- Defect Detection"**, and **"On Line Inspection Systems"**. The former is to determine the feasibility of using machine vision and pattern recognition for on line product inspection of specific attributes, as is already being done in some other industries. The second is to study the feasibility of using robotics on line to perform inspection and test tasks, perhaps aided by machine vision. Design of end effectors to grasp and move pouched food products without damage is in progress.

One practical project addresses the on-line determination of acceptability of the weight of a can of product. It is important to determine that the weight is acceptable before the can is seamed and retorted, so that timely adjustments can be made. The normal method is to manually weigh individual cans, which is slow, tedious, inaccurate, and expensive. The highly practical technology improvement that resulted is the **"Integrated Conveyor for the Tray Pack Can Filling and Seaming Line"**. In addition to being fully integrated with the can seamer, it features an automated weigh scale which is followed by a segment of diverting conveyor that is integrated with the scale. The specified weight and range of acceptability is programmed into the scale, which operates very accurately as product passes over it, and diverts any cans out of the specified range. This type of weight determination is essential for high speed filling lines, but is also practical where manual filling of complex products is performed.

Several other STPs are currently being developed:

- Automated Ingredient Filling Systems (Robotic food item placement with vacuum end effectors)
- Optimize Retort Sterilization (Sensors for pressure, temperature, and time, and process controllers using PLCs for accuracy and repeatability)
- Automatic Retort Rack Loading/Unloading (robots and PLCs to gently place food packages into the sterilization racks and later removal)
- Hybrid Microwave/Retort Sterilization (Sensors for temperature and pressure integrated over time for process control.

Dr. J. L. Rossen is the Principal Investigator. He can be reached at Rutgers by telephone (908) 932-8306.

MILITARY SEWN PRODUCT AUTOMATION (MILSPA)

Military Sewn Products Automation (MILSPA) is a major DLA thrust, established in 1987, to develop and implement advanced manufacturing technology in the apparel industry. Three Advanced Apparel Manufacturing Technology Demonstration (AAMTD) centers have been established at Clemson University, Georgia Tech/Southern Tech and Fashion Institute of Technology in New York. These centers have over 40 projects underway, in a variety of areas, including ergonomics, computer simulation, economic justification of advanced technology, flexible manufacturing methods, design for manufacturing and assembly, and four projects in Intelligent Processing Equipment. Apparel equipment must possess two characteristics in order to be commercially viable: it must be economical to buy and operate and it must be robust.

In-Process Quality Control In Apparel Production: Sewing Defects

This research and development task has the goal of providing an automatic, in-process quality control system for the detection of sewing defects as they occur. The root causes of sewing defects are ply misalignment, thread breaks of top or bobbin threads, and needle damage. The project efforts include identifying and analyze causes of common types of sewing defects, and developing methodologies and hardware systems to automatically detect and report or remove these defects during the production process.

Techniques that have been successfully demonstrated include acoustic energy analysis, similar to acoustic emissions work, and use of a piezoelectric sensor to sense sewing thread motion. Acoustic energy sensors utilized in this work had band-widths which allowed sensing up to 1 MHZ in frequency. A digital recording oscilloscope and PC based analysis packages for time to frequency domain analysis were available to the research. The findings showed that the sewing machine does indeed produce signals that vary with fault conditions.

Thread breaks are positively identified. Defects such as thread line presence and number of fabric ply have been investigated by means of acoustic analysis. The steps involved include taking numerous data points and applying a Fast Fourier Transform to the data to acquire a spectrum of amplitude versus frequency. Data transformed to the frequency domain can be averaged over multiple cycles, smoothed, and thereby analyzed for differences in spectra when defects are introduced.

Work on detecting the number of piles via thread length consumption measurement (sensed by piezoelectric pick-up of acoustic energy) also showed promise progress. One ply versus two or three plies can be detected by monitoring a band of energy centered around 8.750 KHz.

Defects caused by variations in thread take-up consumption is also under consideration. Eltex piezoelectric sensors have a good chance of detecting thread consumption in sewing. Results of work will be reported to Eltex.

In addition, work has pursued on the detection of needle wear by means of detecting amplitude changes in a acoustic spectrum. Dull needles can break the individual threads, causing visible defects in the garment and weakening the fabric at the seam. The needle is a fairly precisely manufactured beam which deflects under the loadings presented in the sewing environment. Using a piezoelectric transducer that picks up sound, researchers measured the acoustic energy given off by sewing needles that had been subjected to varying degrees of wear. The increase in amplitude was proportionate to the amount of needle wear.

An electronic filter designed around an operational amplifier and a voltage comparator provide a design base for development of an inexpensive means of notifying an operator or repair technician that a sewing defect has occurred.

Professor L. Howard Olson, School of Textile Engineering of Georgia Institute of Technology, has conducting this work since 1989. A follow-on effort in developing prototype devices for use in sewing plants with reliability and cost as major factors is in the design process; results of this work should be available in about a year. Professor Olson's telephone number is (404) 894-2534.

<u>Robot Assisted Material Handling For Shirt Collar Manufacturing</u>

The objective of this project is to develop and demonstrate an economical robotic cell controller that is capable of learning during handling of flexible materials, such as shirt collars. The RFHS consists of an industrial robot, sensors (vision system and/or tactile and proximity sensors) and fabric handling end-effector. This system will have the capability to be integrated with a conventional apparel joining machine for demonstrating the feasibility of the concept.

The scope of this project consists of: (1) Design and development of a sensor-based RFHS that is capable of consistently acquiring, handling, manipulating and positioning shirt collar components. (2) Demonstrate that the integration of the RFHS with a selected sewing or joining machine creates a flexible and adaptive shirt collar work station.

This research has involved the conceptualization, design and development of an advanced proof-of-concept shirt collar turning and pressing process based on "double point collar turning and pressing". A proof-of-concept apparel assembly workstation (AAW) has been developed as an experimental test bed to evaluate the automated double point turning and pressing of collars. This work station uses a robot apparel material handler to manipulate flexible shirt collars through automated double point turning and pressing devices. Conceptual development work is continuing on the integration of the turning and pressing devices into a single production machine system.

With extensive involvement of a domestic equipment vendor, additional research and development has been conducted on prototype advanced machines and process technology for temporarily folding and creasing shirt collar bands for automated machine assembly to shirt collars. Work is in progress on the control of a high speed motion controlled sewing head for joining the collar band and collar in the assembly workstation.

Professor Frank W. Paul, McQueen Quattlebaum Professor, Mechanical Engineering Center for Advanced Manufacturing of Clemson University has successfully conducted this research project since 1989. Professor Paul's telephone number is (803) 656-3261.

Automated Handling of Garments for Pressing

The objective of this project is to acquire and demonstrate the knowledge necessary for an automated pressing system which loads a complete garment or sub-assembly on a form and straightens it out for pressing.

The foundation technologies needed to develop further to achieve the goals of automating more of the manufacturing process in apparel manufacturing are:

Material Modeling - modeling of limp materials (i.e., fabric and garments),
Vision - sensing of positions and conditions (e.g., wrinkles),
Automated Handling - grasping and manipulation of garments, and finally
System Integration - three aforementioned elements must be integrated into one intelligent, automated system.

The research successfully demonstrated the feasibility of systems to do modeling sensing the trouser seams and loading and smoothing the fabric on the pressing bucks. Commercially available equipment and systems were used to the maximum extent practicable. The S-700 Robot which is provided by General Motors Fanuc Robot Company has been utilized as a research tool for the purpose of defining and developing the knowledge and subsystems. For example, by changing the end effector on the robot the researchers were able to load the pressing buck, scan the trousers for wrinkles and smoothing the wrinkles.
Significant results have been achieved in the following areas:

Grasping and Manipulation - An array of devices were developed to handle a complete garment. These devices are focused on three specific manipulation objectives: seam alignment, garment transfer, and garment smoothing.

Vision - In this effort, vision is not seen as an exotic sensing concept, but rather, an approach which is both robust and powerful, able to quickly detect seams and wrinkles in a variety of patterns and weights, and on a variety of buck shapes.

Modeling - The models that are developed in this program are models of cloth as an engineering material. They reflect the bending, stretching and slipping of threads as real cloth does, and predicting cloth behavior even employ them in the engineering process and effectively link the design and manufacturing processes in the garment making industry.

Control Systems - The system which is being developed to program, control and integrate the material handling and pressing operations provides a new level of capability for automation in the garment industry. The key asset to this system is that it is a systematic approach where the controller is based on a model of the system. This allow a more error-free and automated transformation from the functional definition of the control system to the control logic.

Professor Aaron Schorr of Fashion Institute of Technology together with several technical staff from the Center for Manufacturing Production and Technology Transfer of Rensselaer Polytechnical Institute, jointly conducted the research work from 1989 to 1990. Professor Schorr's telephone number is 212-760-7855.

SDIO PRODUCIBILITY AND MANUFACTURING INTELLIGENT PROCESSING PROGRAMS

by

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Since its inception, the Strategic Defense Initiative has been primarily a technology development and demonstration program. This initial mission was to determine what technologies could be employed to defend the U.S. against a formidable array of ICBMs launched from the Soviet Union. We had to look at technologies and systems that would defeat Soviet systems available in the mid-eighties, but also we looked ahead 10-20 years at advanced systems and countermeasures. Anything we proposed using these technologies would have to be survivable, affordable, and cost effective at the margin. These three criteria drove SDIO toward concepts that relied heavily on smaller, faster, lighter components whose robustness would be achieved by high reliability and fault tolerant designs. These initial architectures require a robust U.S. industrial base that would not only be able to produce and assemble the light weight space vehicles; cheap and reliable infrared sensor systems; ultra-compact, high energy propulsion systems; advanced communication systems, etc......but also be able to smoothly and effectively transition from Phase I technologies to more advanced technologies such as lasers and neutral particle beams that would be required to address a steadily progressing Soviet threat.

Translating there new technologies from laboratory demonstrations and initial flight test vehicles into batch and quantity production lines with scores of new manufacturing processes and quality monitoring techniques was.....and continues to be.....a major undertaking. SDIO has, and continues to , work through executing agents: the Army, Navy, Air Force, Department of Energy, DARPA, NASA, and Commerce. We use the capabilities of available U.S. infrastructure and expertise. In this way, the precision fabrication and measurement capability of the U.S. would be brought to bear on the SDIO challenges. From a manufacturing perspective, however, most of these capabilities represent R&D type prototype production facilities at best. The history of space and strategic systems has been one of insertion of the best technology available at whatever cost on a batch of systems made only a few at a time.

The type of space based and ground based systems envisioned by SDIO would not be able to tolerate the labor intensive testing and retesting, nurturing, and redundancy present in many of our current space and strategic missile systems. Precision and reliability would have to be built-in and be predictable and affordable. Let me just mention some of the areas for application of these precision manufacturing principles: cryocoolers that would operate at liquid nitrogen temperatures and others at 40° and 10° K; large scanning and staring infrared focal plane arrays who would possess a maximum amount of on-array processing; precision guidance systems for satellites that use precision bearings and gimbals; high frequency communication amplifiers, antennas, and the high volume production of those components; advanced, low weight materials ..... including those employing both active and passive dampening; small, light weight, thin walled propulsion and direct propulsion systems for interceptors that require precision control and nozzles; precision, light weight, complex optics systems that are both endurable and survivable.

To address all these areas, SDIO has to fashion a comprehensive strategy to insert the capability of our industrial base into ongoing design trade-offs. This means that we not only need to determine _if_ something can be made to the precision we need to meet system performance, but also what changes need to be made in that industry sector to develop a deterministic approach to fabricating precision components. Developing and introducing advanced production and quality control systems is part of this process. Yet, most SDIO production contracts are still in the future.

To address this situation, SDIO has developed the MODIL (Manufacturing Operations Development and Integration Laboratories) program. The balance of my talk will deal with the MODIL program and Intelligent Processing Programs being accomplished through these MODILs.

SDIO PRODUCIBILITY AND MANUFACTURING INTELLIGENT PROCESSING PROGRAMS

MODIL Programs have been established as a result of a comprehensive risk mitigation strategy within SDIO. High risk areas have been identified in which industry simply does not have the capability to meet SDI needs.

MODILs have been established in three areas; Survivable Optics, Electronics and Sensors and Spacecraft Fabrication and Test.

WHAT IS A MODIL

The MODIL Programs fill the gap in producibility between design and FSD. No other mechanism directly addresses producibility and manufacturing issues prior to FSD.

The MODILs have been established to accelerate the development and transition of high payoff technologies critical to SDI, for which industry does not have the capability nor the incentive to do alone. The MODILs fund industry to develop intelligent manufacturing processes, and provide a test bed facility to demonstrate advanced processes and state of the art equipment allowing industry to gain hands on experience at minimal cost. This approach is intended to benefit the smaller DoD vendors who do not have the capital resources to develop new processes.

SURVIVABLE OPTICS MODIL

As I mentioned before, optical components have been identified as a high producibility risk. The typical cost for an SDI mirror (1989) is approximately $1M/square meter. Analysis of the processes used to make mirrors showed that a realistic goal for high precision mirror procurement is $50K/square meter. By reducing the number of processing steps and inserting a high degree of determinism into the processes, the MODIL believes this goal is achievable. A major thrust within the Optics MODIL is In- and On- Process Metrology. Currently, metrology is used off-line, requiring iterative transport and refixturing to and from the metrology facility. Adapting metrology techniques to fit <u>on</u> the processing equipment will eliminate refixturing and transport. A step further entails developing a metrology system which makes measurements <u>during</u> the processing permitting the implementation of feedback loops. Automated, fully deterministic processing will achieve the highest cost and lead time reductions.

SURVIVABLE OPTICS MODIL TECHNOLOGIES UNDER DEVELOPMENT

Three on-process figure metrology techniques are being developed through the Optics MODIL. The differential interferometer, a Breault Research Organization Phase Shifting Interferometer, measures only the change in optical figure (consequently it is immune to aberrations), information which is required for temperature stability measurements and well suited to measuring the improvement in figure during manufacturing processes such as ion milling. Development entails enhancing the instrument by adding high definition electronic image processing and aspheric measurement capability by using computer generated holograms. On-process capability will be demonstrated first on the ion milling machine.

Polarization Interferometry offers vibration immunity and easy alignment; both essential for in- or on-process metrology. The polarization shearing interferometer system under development has high potential for providing an inexpensive on-process method of phase measurement interferometry for aspheric optics.

The Scanning Hartmann Measuring Device is presently the most promising type of system for on-process figure measurements during single point turning and ductile grinding operations. It is a non-interferometric system which utilizes an X-Y position sensor to detect the point reflection from the mirror being machined. Automation of the data acquired by this device will be used to better define and control the turning process.

SURVIVABLE OPTICS MODIL TECHNOLOGIES UNDER DEVELOPMENT

Advancement in the state of the art of single point turning, ion milling and ductile grinding has produced as machined surfaces with surface roughness levels acceptable for SDI applications. While eliminating the need for polishing, this achievement generates the need for on-process finish measurement capability. The MODIL is funding development of a prototype instrument which will be demonstrated in the MODILs test bed.

On-process subsurface metrology seeks to identify substance material characteristics which would adversely affect the performance or fabrication of a component. Such characteristics include residual stress, subsurface cracks, and material inhomogeneities. Five techniques have been reviewed (eddy current, x-ray, ultrasonic, micro-raman, IR ellipsometry) and two look the most promising for on-process use: IR Ellipsometry and Micro-Raman Spectroscopy.

ELECTRONICS AND SENSORS MODIL MISSION QUALIFIED ELECTRONICS FOR SIGNAL PROCESSING

Consistent with total quality management (TQM) principles, the U.S. Government has proposed QML methodology to qualify integrated circuits for high reliability and radiation hardness. In this approach, a production line is certified on a "one time" basis, and all products from that line are subsequently qualified per the requirements of MIL-I-28535. This built in quality is assured by the proper control of the IC manufacturing sequence from design through assembly. Through use of its extensive knowledge base, the Electronic and Sensors MODIL will develop the most practical, cost-effective implementation of QML.

The key near-term activities required for cost-effective QML include 1) development of predictive models and accelerated screens for IC failure mechanisms, 2) identification of in-line process controls for radiation and reliability, and 3) wafer level acceptance testing.

ELECTRONICS AND SENSORS MODIL ADVANCED SENSORS

Molecular Beam Epitaxy and Metal Organic Chemical Vapor Deposition have both been established as viable manufacturing processes for synthesis of the active Strained Layer Superlattice layers. Both techniques lend themselves to a number of in-situ materials characterization techniques.

Compositional control can be achieved using reflection mass spectroscopy for MBE and UV absorption for MOCVD. Superlattice quality is characterized using double modulation photoluminescence spectroscopy. All of these characterization techniques are being applied at the wafer level and can be applied to a variety of focal plane array manufacturing processes.

DUCTILE GRINDING INITIATIVE

SDI has endeavored to integrate the fragmented experts performing research and development of ductile grinding, a high payoff technology for manufacturing of optical components for SDI and a technology with tremendous spin-off potential. The primary participants are NIST, LLNL, and the Optics MODIL. The Cranfield Unit for Precision Engineering in Great Britain is participating in a unique way. SDI is funding them to develop a precision grinding machine unlike any other. The machine consists of a tetragonal space frame in which the grinding spindle is held. The structural members provide an ultra-stiff frame work and vibration damping; both necessary for optimal grinding in the ductile regime. The Optics MODIL is also investigating advanced machinery for ductile grinding. The will be demonstrating ductile regime grinding on the commercially available state-of-the-art Manoform 600 turning machine.

Other efforts at the National Labs and Universities will focus on more basic research understanding the fundamental principles of plastic removal of brittle material. The key parameters will be determined and the parametric boundaries of the ductile regime defined. Because of the sensitive nature of the ductile/brittle transition, sensors will be developed for real time control of the process. Acoustic Emission and Specific Grinding Energy are two promising real time sensor techniques.

SDIO PRODUCIBILITY AND MANUFACTURING INTELLIGENT PROCESSING PROGRAMS

- Manufacturing Operations And Development Integration Laboratory (MODIL) Programs
  - Survivable Optics
  - Advanced Sensors
  - Space Qualified Electronics For Signal Processing
  - Spacecraft Fabrication And Test
- Ductile Grinding Initiative
  - Consortium Of Domestic And Foreign Experts

WHAT IS A MODIL?
(MANUFACTURING OPERATIONS AND DEVELOPMENT INTEGRATION LABORATORY)

Technology Transfer Mechanisms

- University Research Institutes
- Other Government Programs
- Private Industry

Research And Development

Technology Developments

High Payoff Technologies

- Iterative Enhancement
- Order Of Magnitude Improvements

MODIL

New, Enabling Technologies For Transitioning From R&D / Technology Base To Manufacturing / Production Phase

IMIP

Factory

Affordable Products

System Elements

Accelerates Development And Transitions Technology To Affordable Products

SURVIVABLE OPTICS MODIL

Problem

- Lack Of Deterministic Processing In Optics Industry
  - Mirror And Lens Making Is Still An "Art"
  - Not Conducive To Production Of High Precision Components
- Metrology Used In Off Line Fashion
  - Fixturing And Transport Is Time Consuming And Labor Intensive

Solution

- On-process Metrology
  - Measurements Made Without Removing Workpiece
  - Eliminates Refixturing And Transport
- In-process Metrology
  - Measurements Made During Processing
  - Permits Use Of Feedback Loops To Control Material Removal

SURVIVABLE OPTICS MODIL TECHNOLOGIES UNDER DEVELOPMENT

Figure Measurement

- **Differential Interferometer**
  - **On-process Potential - Will Be Integrated Into Ion Milling Chamber Providing Real Time Feed Back To Ion Gun**

- **Polarization Interferometer**
  - **Inexpensive, Common Path Stability, Easy Alignment On-process Potential For Measuring Aspheric Optics**

- **Scanning Hartmann Measuring Device**
  - **In-process Potential During Single Point Diamond Turning, Non-interferometric, Fully Automated Scanning And Feedback For Real Time Control**

SURVIVABLE OPTICS MODIL
TECHNOLOGIES UNDER DEVELOPMENT (Cont'd)

Finish Metrology

- Prototype On-process Scatter Measurement System

Subsurface Damage Metrology

- IR Ellipsometry
- Raman Scatter

ELECTRONICS AND SENSORS MODIL

Advanced Sensors

- IR Sensor Manufacturing Technology
    - MBE And MOCVD Of Active Strained Layer Superlattice (SLS) Layers
    - MBE And MOCVD Processes Allow Insitu Characterization
- Wafer Level Insitu Characterization For Insitu Control
    - Reflection Mass Spectroscopy (REMS) And UV Absorption
    - Double Modulation Photoluminescence Spectroscopy

ELECTRONICS AND SENSORS MODIL (Cont'd)

Mission Qualified Electronics For Signal Processing

- **Radiation And Reliability Assurance**
  - SDI System Elements Depend On U.S. Commercial Microelectronic Products
  - MODIL Provides Near Term High Payoff Fixes Enhancing Radiation And Reliability Performance Of Commercial Microelectronics
- **QML In-line Monitoring**
  - Development Of Predictive Models And Accelerated Screens For IC Failure Mechanisms
  - Identification Of In-line Process Controls For Radiation And Reliability

DUCTILE GRINDING INITIATIVE

Ductile Grinding: A Promising Technology For Cost Effective Production Of Precision Optical Components Made Of Brittle Materials

Benefits

Minimizes Or Precludes Polishing

Minimal Subsurface Damage

Stronger Surfaces

Fewer Processing Steps = Lower Cost

Challenges

Determine Key Parameters

Define Parametric Boundaries Of Ductile Regime

Perform Economic Comparison To Other Processing Options

Develop Real Time Sensors for Intelligent Processing

MANUFACTURING TECHNOLOGY INFORMATION ANALYSIS CENTER: KNOWLEDGE IS STRENGTH

by

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ABSTRACT

The Manufacturing Technology Information Analysis Center is funded by the Department of Defense and supports the DoD ManTech Program. The Center's primary function is to facilitate technology transfer within DoD, other government agencies and industry. The Department of Defense has recognized the importance of technology transfer, not only to support specific weapon system manufacture, but to strengthen the industrial base that sustains DoD. This presentation will focus on MTIAC's ability to foster Government/Industry cooperation through the transfer of manufacturing technology. MTIAC utilizes an experienced technical staff of engineers and information specialists to acquire, analyze, and disseminate technical information. Besides ManTech project data, MTIAC collects manufacturing technology from other government agencies, commercial publications, proceedings and various international sources. MTIAC has various means of disseminating this information. Much of the technical data is on user accessible data bases. The Center researches and writes a number of technical reports each year and publishes a newsletter monthly. Customized research is performed in response to specific inquiries from government and industry. MTIAC serves as a link between Government and Industry to strengthen the manufacturing technology base through the dissemination of advanced manufacturing information.

INTRODUCTION

Department of Defense Instruction 4200.15 defines manufacturing technology as, "Information that is, will be, or may be used to define, monitor, or control processes and equipment used to manufacture or remanufacture DoD materiel." This is, of course, part of the Manufacturing Technology Program Instruction. I plan to use the first part of that definition, *"manufacturing technology is information,"* to introduce an information hierarchy. I will relate that to the field of manufacturing.

Terms such as information, data, knowledge, facts, or news all relate to the general concept of information. Placing these terms into a hierarchy makes it easier to evaluate the importance of information.

We normally define "data" as directly observable facts. Individual pieces of data have no meaning unless we place them in a context. The fact that titanium has a certain hardness lacks meaning until you try to machine it.

The next level in our hierarchy is "information." Information is a structured collection of data. Facts and figures are organized in relation to each other and to the overall theme of the information. The collection of data on titanium with data on cutting speeds, tooling, coatings, etc., constitutes information about machining titanium.

The final level in the information hierarchy is knowledge. Knowledge means you know how to use the information. For example, applying the information you have about the machining of titanium to a specific situation in a specific factory constitutes knowledge. Knowledge is the process of deciding what information to apply to a specific requirement. The value of the data increases as it moves up the information hierarchy.

How does all this relate to the Department of Defense and the Manufacturing Technology (ManTech) Program?

DoD has long recognized the need for investment in and support of manufacturing technology. DoD normally relies on the private sector to provide the manufacturing technology necessary to produce DoD materiel. But DoD must often invest in manufacturing technology advancements when the private sector cannot or will not meet defense needs in a timely manner. DoD depends upon the U.S. industrial base. Thus, any benefits accrued through ManTech investment will probably benefit DoD. The ManTech Program is over 25 years old. It has a substantial string of success stories. The output of the ManTech Program is information. It has many uses. Many people can use it at the same time. It is infinitely replicable at relatively low cost. It has value only if people use it. Dod must manage this information if it is to be of any value. DoD established the Manufacturing Technology Information Analysis Center (MTIAC) to help manage information.

MTIAC BACKGROUND, SCOPE, AND MISSION

Information management is not a new DoD topic. The Information Analysis Center Program grew from DoD needs to manage technology in specific subject areas. The IAC Program is over 30 years old. It encompasses over 25 centers. Technical areas range from materials (metals, ceramics, metal matrix composites) to specific technologies (guidance and control, chemical propulsion, manufacturing). These centers provide similar products and services within their technical scope. The Defense Technical Information Center in Alexandria manages many DoD information analysis centers. MTIAC can send you a complete list of these centers.

DoD tries to locate these centers within organizations that have substantial additional resources in the IAC's subject specialty. The Manufacturing Technology Information Analysis Center is operated by IIT Research Institute in Chicago, Illinois. Most of you know us as IITRI. IITRI performs considerable manufacturing research for both the government and the private sector. MTIAC can draw on all the resources of IIT Center, which includes IITRI, Illinois Institute of Technology, the Gas Research Institute, and the 20 other affiliated organizations.

MTIAC has an experienced core staff of engineers and information specialists. These are supplemented by the staff and faculty of IIT Center. The core staff is in place to handle the ongoing activities of the center. Our subject specialists assist in specific tasks as required.

The scope of MTIAC includes all aspects and areas of manufacturing technology within the purview of the DoD Manufacturing Technology Program. It includes such areas as electronics, composites, metals, CIM, quality, and munitions.

MTIAC's mission is to support the ManTech Program. Its objective is to improve the productivity and responsiveness of the defense industrial base. To accomplish this mission, MTIAC collects, analyzes, and disseminates timely and pertinent information describing industrial technologies, processes, and techniques.

MTIAC OPERATIONS

Information management for MTIAC consists of three phases: collection, analysis, and dissemination. The information hierarchy outlined above is a good model of MTIAC operations.

Our first step is to collect information on manufacturing technology. MTIAC subscribes to over 100 trade publications, magazines, and journals that cover the various aspects of manufacturing technology. Our collection includes shop floor publications (Modern Machine Shop), academic periodicals (International Journal of Production Research), professional titles (Manufacturing Engineer), and defense-related magazines (Jane's, Defense News). We review these subscriptions for manufacturing technology information.

We also collect manufacturing conference proceedings. They provide a fertile source of contemporary information. Our staff members also routinely attend technical conferences to gather information.

Government and industrial technical reports contain valuable manufacturing technology. MTIAC has a complete collection of ManTech final reports. We also compile reports from other government agencies and private industry.

Other sources of manufacturing technology include books, video tapes, pamphlets, product literature, and computer software. Information about much of the leading edge technology is collected through personal interviews with manufacturing experts.

As I pointed out earlier, MTIAC is not just a repository for unorganized information, but an information resource. The second step in information management is the analysis and organization of the information collected. MTIAC uses state-of-the-art computerized data bases to perform this function.

MTIAC maintains three computerized data bases, and each containing different types of information. The largest data base is the bibliographic data base of references to manufacturing technology literature. Information collected from journals, proceedings, and reports is categorized by subject or keywords by technical specialty. Other details, along with an abstract and keywords, go into the data base for retrieval as needed. We now have over 10,000 references in the data base. An information specialist can isolate those materials that deal with a specific technology within seconds. This data base is part of the much larger DoD research and development data base. It supplements this data base and, at the same time, draws on its vast collection of, technical information.

SIMON is the DoD ManTech Project Data Base developed by the Office of the Secretary of Defense (OSD) to help the ManTech Program. SIMON currently contains roughly 1900 records of ongoing or completed ManTech projects. MTIAC has a public domain subset of this data base. It can be accessed directly or through the MTIAC staff. It is available to any contractor with export control clearance.

MTIAC on-line services, including SIMON, is a user-accessible collection of files of interest to the ManTech community. These data bases include the Directory of Manufacturing Research Centers, the Manufacturing Technology Advisory Group (MTAG) Points of Contact List, ManTech End of Contract Demonstration dates, and a meetings calendar.

MTIAC also maintains the more traditional types of collections. We have a technical library, a document library, and referral information.

The technical library includes all the journals, books, proceedings, video tapes, and newsletters that come into the Center. This is the "public collection" and is available for on-site use by researchers.

The document library contains the technical reports, journal articles, and other materials referenced in the bibliographic data base in either hard copy or microfiche. This collection includes considerable export controlled information.

The referral information is organized by a variety of subjects to facilitate easy access. This file contains all the miscellaneous information related to manufacturing technology but is ephemeral in nature. It includes product information, newsworthy items, company information, government programs, and anything not covered in the other information collections.

Information dissemination is MTIAC's final step in information management. Information has no value until it is applied and becomes knowledge. Dissemination, or application, involves two separate components: information packaging and information recipients. Information must be in a format compatible with the situation. It must go to the right individual.

MTIAC packages information for dissemination in several ways. What we do depends on both the user and the application. We use inquiry responses, standardized reports, customized reports, and a current awareness bulletin.

Response to technical inquiries is the most timely service provided by the Center. In response to a technical question, the MTIAC staff search our information base for relevant information. After locating material, we analyze the information for applicability to the inquiry and organize the information into an understandable format. An evaluation is prepared and delivered to the requester. Response to technical inquiries can be very fast. Sometimes we are able to research within the same working day. More often, however, it takes 2 to 3 working days. Referral inquiries requiring simple factual information are usually handled within the same working day, frequently on the original phone call.

By constantly reviewing manufacturing literature, MTIAC is often able to identify manufacturing trends in new technologies. These trends and technologies also tend to be areas receiving numerous inquiries. MTIAC will often prepare a general report on high interest topics. The level of effort for these special reports varies from a literature survey and analysis (technology assessment) to an in-depth review of that technology (state of the art report). Occasionally we prepare a comprehensive reference work (handbook). Some examples of MTIAC reports include:

Technology Assessments	Rapid Prototyping
	Sensor Fusion for Manufacturing
State-of-the-Art Reviews	Higher Order Languages for Robots
	Automated Inspection for Flexible Machining Systems
	Laser Cutting
	Vision Technology for Automated Inspection of Hybrid Microelectronics Assemblies
Reference (Handbook)	Directory of Manufacturing Research Centers

When a technical inquiry requires a more in-depth review and analysis, MTIAC can produce customized reports tailored to the needs of the inquirer. In these instances, MTIAC staff review the scope of the research with the requestor and outline an approach. The requestor usually funds and directs these efforts. DoD agencies often take advantage of this capability. Some customized reports MTIAC has produced are:

Manufacturing Technology Research Needs of the Gear Industry - Defense Logistics Agency

Computer Integrated Manufacturing: Concepts and Applications - Army

Process Control - Army

MTIAC also disseminates information through the monthly newsletter, the Current Awareness Bulletin. This newsletter contains current information of interest to the manufacturing community. It includes meeting reviews, feature articles on manufacturing technology, reviews of current literature, information on ongoing

ManTech projects, End-Of-Contract Demonstrations, bibliographies, announcements, and any other relevant information. The CAB is free. We'll be happy to mail it to any interested party.

The means of dissemination of manufacturing technology frequently depends on the information user. MTIAC strives to match the appropriate information to the appropriate user for maximum value. Although the Department of Defense funds MTIAC for the support of the ManTech Program, the Center has a diverse user group.

Our primary user community is the DoD ManTech Program staff. We provide support to OSD; Army, Navy, Air Force, and DLA Program Managers; project managers; and the MTAG Subcommittees. MTIAC also serves other DoD users including DARPA and SDIO and other government agencies including the National Institute for Standards and Technology, NASA, Department of Commerce, DOE, and the General Accounting Office.

MTIAC provides considerable assistance to contractors. The Center's products are normally designed to make them available to contractors for a minimal sum. MTIAC is also a national resource to the entire U.S. manufacturing community. The Center's services are available for nominal fees. MTIAC provides the CAB and some referral services at no charge.

MTIAC - INFORMATION AND MANUFACTURING

Just where does information analysis fit into the manufacturing project cycle? MTIAC can be valuable at all stages of a manufacturing project.

Conceptualization - The stage where a problem is identified. Information analysis can clarify the technical aspects of the problem and provide background on and definitions of the related manufacturing technologies. Information analysis can be very valuable by suggesting technical solutions.

Startup - Before starting a manufacturing technology project it is imperative to determine whether any other ongoing or completed research exists in the same area. This avoids duplication, takes advantage of previous lessons learned, and maximizes research dollars.

Project - As problems arise during the project, manufacturing information analysis can provide alternative technical solutions.

Completion - Data collected during the project can be evaluated and added to the information base for future applications.

CONCLUSION

The value of manufacturing technology cannot be overstated. At every stage of a manufacturing project, information is a necessary component of the end product. MTIAC is a national resource, making manufacturing technology information available to the entire manufacturing community.

INTELLIGENT PROCESSING EQUIPMENT WITHIN THE ENVIRONMENTAL PROTECTION AGENCY

by

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ABSTRACT

Protection of the environment and environmental remediation requires the cooperation -at all levels- of government and industry. Intelligent processing equipment, in addition to other artificial intelligence based tools, has been used by the Environmental Protection Agency to provide personnel safety and improve the efficiency of those responsible for protection and remediation of the environment. These exploratory efforts demonstrate the feasibility and utility of expanding development and wide spread use of these tools. A survey of current intelligent processing equipment applications in the Agency is presented and is followed by a brief discussion of possible uses in the future.

BACKGROUND

Scientists continue to learn that the by-products of current industrial practices and modern life styles adversely affect the global environment. Concerns about global warming and destruction of the ozone layer are wide spread. Consequences of improper disposal and treatment of hazardous and nuclear wastes also have the potential for widespread environmental deterioration. Many environmental issues must be addressed and resolved at the local, regional, national, and international level. Due to the high costs of preventing or minimizing environmental contamination in addition to rectifying existing damage, cooperation is imperative at all geo-political levels. Comprehensive regulations and enforcement practices are clearly necessary. Effective and efficient decision making coupled with state of the art technologies are also integral to minimization of environmental contamination, treatment of hazardous substances, and disposal of residues.

The Agency has begun to develop and use artificial intelligence tools, including intelligent processing equipment to address high priority environmental concerns. Due to the high costs of environmental controls and the implications of inadequate practices, it is imperative that governments and industry cooperate in the development of environmentally directed intelligent processing equipment (IPE). This involves sharing of information about state of the art methods, collaborative research and development activities, and expansion of relevant professional intellectual property at all levels in governments and industry. These objectives for environmental applications of advanced control and treatment technologies fits right in with the objectives stated in the Intelligent Manufacturing Systems proposal[1].

The Environmental Protection Agency mission is defined through several more recently passed environmental laws including:

- National Environmental Policy Act (NEPA) 1969
- Toxic Substances and Control Act (TSCA) 1976
- Resource Conservation and Recovery Act (RCRA) 1976
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 1980

- Hazardous & Solid Waste Amendments (HSWA) 1984
- Superfund Amendment Reauthorization Act (SARA) 1986
- Safe Drinking Water Act (SDWA) 1986
- Clean Air Act (CAA) 1990

The Agency also has responsibility for protecting human health and the environment from adverse effects of anthropogenic (man made) activities. This requires state of the art capabilities to assess extent of contamination, estimate health and environmental consequences of exposures, and evaluate alternative methods for remediating contamination. The Agency has developed and is evaluating a variety of artificial intelligence tools including knowledge-based systems, neural computing systems, robotics, and sensors to meet these responsibilities.

Knowledge-based systems have been developed to assist Agency decision makers in their evaluation of selected scenarios. Examples include, review of closure plans for hazardous waste land disposal sites, performance of human health risk assessments, development of sampling plans for metals in soils, and identification of regulations that must be complied with when cleaning up a Superfund site. Few of the systems are "true" expert systems in terms of a pure academic definition which specifies that the system be a model of the reasoning process of live experts. Much of the encoded information is extracted from Agency approved written sources. Several of the systems are, or could be, user friendly data base applications as well. In any event, they are all attempts to improve the awareness and increase the efficiency of Agency decision makers and to improve the quality of their decisions. Few, if any of the systems currently available, are routinely used by environmental decision makers. The reasons for this lack of usage is a general lack of awareness of the benefits of knowledge based systems.

Neural computing approaches are being used to explore existing Agency data sets. The objective is to derive predictive models that are better than those that have been postulated using traditional model development methods. One example is a system to predict the resistance of chemical protective clothing. Steady-state permeation rates are estimated from knowledge about solubility, diffusivity, and thickness of the chemical protective clothing material[2,3]. Another example is evaluation of the structure of a chemical treatability data base. The idea is to use existing data to develop treatment performance parameters which can be used to predict treatment performance for new concentrations/combinations of chemicals[4].

The Agency has had limited environmental application experience with IPE. Since the Agency is primarily a regulatory Agency IPE has not been used as much as in some other government organizations whose missions include technology development, production, and manufacturing. It would probably be correct to say that IPE is in its infancy stage in the U.S. EPA. Much growth, however, is expected in the future.

A few exploratory projects have been conducted and limited development has occurred to assess the potential of robotic systems in the Agency. A prime motivation for these systems is protection of workers from exposures to hazardous and radioactive substances. Other applications for the systems might include increases in productivity and improved quality of analytical measurements.

Carnegie Mellon University has been receiving Agency support to develop robots that can be used to evaluate and describe hazardous waste sites. A demonstration project has been conducted where an existing tele-operated robot was modified to include autonomous navigation and perform hazardous air monitoring on a hazardous waste site[5].

Another project developed proto-typical robots to position ground penetrating radar equipment with the accuracy needed to generate three dimensional subsurface maps[6,7]. An Instrumented Robotic Assistant (IRA) has been proposed as a mobile infrastructure that hauls, positions and supports a variety of field equipment. The IRA is to be an all terrain mobile platform with capability to perform a number of field functions, including position management, computation, provision of power, and communications[8].

Another application being considered jointly with the Department of Energy (DOE) are robotic systems with the capability to measure extent of radiation contamination at DOE facilities possessing radiation hot spots[9]. Robotic systems have also been proposed and some development has occurred to assist in analysis of hazardous waste samples in a laboratory. To reduce possibilities of exposure to hazardous chemicals in laboratories that analyze hazardous wastes, robotic systems have been proposed to work through a glove box type arrangement to prepare and analyze environmental samples[10].

Although the Agency is not a major developer of intelligent processing equipment, it is becoming a bigger user. A foundation exists, through its activities with knowledge based systems and robotic systems, to build a viable intelligent processing equipment program. This paper presents some ideas for possible future inclusion of intelligent processing equipment as a key component of the Agency's technology development activities.

DISCUSSION

Initial uses of intelligent processing equipment have been to minimize the potential exposure of workers to hazardous wastes. As more is learned about the health risks of hazardous wastes it is anticipated that concerns about worker exposure will increase. Hence, the need for unmanned intelligent systems will increase. Some of the current difficulties with using these systems are the irregularity of the surfaces of hazardous waste landfills and the hostility of the contaminants to the vehicles. It is anticipated, however, that the capabilities of these systems and their resistance to the external environment will increase. This could enhance the possibilities for future applications both on hazardous waste sites and in analytical laboratories. Clearly, the rationale for selecting worker safety as the initial applications for these systems is sound. On the other hand, the possibilities for these systems with the Agency's diverse research and field activities far exceeds these initial considerations.

Several technologies have been developed and new ones are being evaluated to treat wastes found at hazardous waste land disposal sites. Examples are:

- Microfiltration Technology for Groundwater Contaminated with Metals
- Soil Vapor Extraction Technology
- Soil Heating Technologies
- Rotary Kiln Incinerators
- Full Scale Industrial Boilers

Typically, these technologies are tested within a laboratory setting, or in a well controlled environment, to determine treatment effectiveness. Special purpose incinerators, for example, are tested to determine the extent of Poly Aromatic Hydrocarbons (PAH) destruction and production of other undesirable by-products. Due to the costs of these technologies and the implications of inadequate treatment, it is very important that the systems operate at the same level of efficiency when deployed as when tested. Sensors, controls, and knowledge-based systems would be considered essential for accomplishing the objectives of these technologies.

Approximately 100,000 environmental samples must be collected and analyzed each year. Continued improvements in analytical equipment permit the detection of smaller and smaller quantities of environmental contaminants with increasing levels of precision. It has been found that the major sources of variability for most analyses are the tasks performed by humans. These tasks, which are integral to most analyses methods, include field sampling, sample preparation, maintenance of laboratory logs. The human element is the weak link in the analytical picture. This situation is expected to get worse as the number of qualified persons declines while the capabilities of analytical equipment continues to increase. One of the EPA's Research Laboratories has proposed a major initiative to evaluate, develop, and implement robotics and sensors to improve analytical capabilities to sample and analyze environmental samples. Robots have the potential to consistently handle large numbers of samples since they can work twenty four hours per day without getting tired. From the EPA's perspective, they can also free up full time equivalent (FTE's), which are in short supply, for tasks that can not be readily mechanized. A robotic system was developed, as a pilot lab project, to prepare environmental samples for metals analysis by microwave digestion. In spite of hardware and software problems encountered it still appears that this system, in addition to others, would be beneficial additions to an environmental laboratory. The other prime motivation for robotic systems is protection of workers from adverse exposures from the environmental samples[10].

Paralleling the effort to evaluate and develop robotic systems to improve equipment operations, knowledge-based systems have been and are continuing to be developed and evaluated to assist environmental decision makers. They can, and have been used, to aid those responsible for policy decisions; the EPA reviewers of permit applications for hazardous waste land disposal sites and On-Scene Coordinators and Regional Project Managers in the EPA Superfund Program. Examples of knowledge-based systems that have been developed, or are being developed, at the Agency include:

- Closure Evaluation System - This set of three modules is designed to assist EPA and state representatives in their evaluation of permit applications that include proposed designs for final covers, vegetative covers, and leachate collection systems for hazardous waste land disposal sites[11].

- A tool to aid in the identification of applicable or relevant and appropriate regulations (ARARS), entitled Potential ARARS Selection Tool (PAST) - The purpose of this tool is to aid in the determination of the regulatory requirements for cleaning up a Superfund site. Both Federal and state requirements will be cited by the system[12].

- Environmental Sampling Expert System - This system aids in the development and/or review of sampling plans to estimate the extent of metal and cyanide contamination of a hazardous waste land disposal site[10].

- Computer-Aided Data Review and Evaluation System - This system assists in the evaluation of the quality of environmental chemical analytical data[13].

- Geophysical Advisor - This system aids in the selection of appropriate geophysical sampling equipment to characterize a hazardous waste land disposal site.

Clearly, the purpose of these systems -improved environmental decisions- is similar to that of laboratory robotic and sensor systems. Both technologies attempt to capture the intelligence of knowledgeable persons and apply it to enhance the environmental decision making process.

Another activity that would appear to be amenable to IPE and knowledge based systems is the development and evaluation of technologies to treat hazardous wastes. The Agency has responsibility for developing and evaluating new technologies to effectively and efficiently treat hazardous wastes. As would be expected, many of these technologies are highly complex. Before application, all of them must be tested to assess effectiveness. Most of these tests are performed by highly trained personnel operated in well controlled environments. Due to the potential health and environmental and economic liabilities associated with an ineffective treatment process, it is very important that actual field performance of the technologies be the same as in the early evaluations. Typically, the field environment will not be as well controlled as the test and evaluation environment. Weather conditions, availability of supplies, etc. may be less than optimum at an application site. Also, the operators of the online treatment system may not be as highly trained as those who conducted the treatment evaluation studies. Hence, the need for IPE and knowledge-based systems to insure that the systems perform up to their potential can clearly be understood.

CONCLUSION

In many respects the Agency is in its infancy relative to the development and use of intelligent processing equipment to accomplish its diverse environmentally comprehensive missions. There are several reasons that can be offered for the relatively slow start in the field. But, lack of need or opportunities should not be considered to be among them. Assessing extent of environmental degradation, identification of all applicable or relevant and appropriate federal and state regulations, and selection of cost effective remediation technologies is a complex and highly technical process. Informed decisions in this arena require that decision makers possess extensive knowledge of both technical and legal issues or at the least must have ready access to such information. The supply of professionals with these credentials is limited. Due to the continuing decline in scientifically trained persons graduating from colleges, it is expected that this shortage will increase. Within the EPA the shortage is exacerbated by competition from industry and consulting firms for highly qualified personnel. All of these conditions speak to the need for increased development and application of artificial intelligence techniques including IPE. It is expected that these needs will soon push artificial intelligence into the mainstream of Agency decision making and operations. The Agency has a nucleus of personnel who have the capability to identify high payoff applications, to actively direct development and evaluation of new systems, and to effectively direct application of these systems. To successfully expand IPE development and implementation within the EPA would require establishment of an identifiable institutional capability within the Agency. In many respects, the institutionalization of IPE should parallel that which was done in the risk assessment area a few years ago. Initial risk assessment activities were performed by a number of highly trained individuals in different parts of the Agency. As the need for uniformity and numbers of risk assessment increased, a formal assessment program was established with the Agency. A similar progression would seem appropriate in the field of artificial intelligence and IPE as well.

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13. Robertson, Gary L., 1991, Computer-Aided Data Review and Evaluation System Development, Summary Report, EPA 600/X-91/133.

ENVIRONMENTAL PROTECTION AGENCY (EPA)
IPE RELATED PROJECTS

List of Intelligent Processing Equipment Projects and Contacts:

Robotics microwave digestion system
Larry Butler (702)798-2114

Instrumented robotics assistant designed to be an all-terrain mobile platform that can be ridden around hazardous waste sites to serve as a local base of operations
Carolyn Esposito (201) 321-6675

Air Monitoring through robotics
Carolyn Esposito (201) 321-6675

Automated Subsurface Mapping
Carolyn Esposito (201) 321-6675

Environmental sampling expert system
Jeff Vanee (702) 790-2367

Permit review aids for hazardous waste land disposal sites
Daniel Greathouse (513) 569-7869

Potential ARARS selection tool
Daniel Greathouse (513) 569-7869

RAMP TECHNOLOGY AND INTELLIGENT PROCESSING IN SMALL MANUFACTURING

Richard E. Rentz
Technology Transfer Manager
South Carolina Research Authority
(803) 760-3241

The Navy, as well as the other armed services, is charged with procuring and maintaining various weapons systems. The practical service life of these systems varies between 20 to 50 years, and, as expected, a number of factors can hamper their support and maintenance over this period. These factors include changes in technology and the loss of the industrial suppliers of certain manufactured items. To overcome these logistics deficiencies and maintain readiness, the services are required to maintain an extensive inventory of spare parts, which carries a multi-billion dollar price tag. In addition, the average procurement lead time--the time required from order to receipt of unstocked parts--currently exceeds 400 days.

To address the issues of excessive inventories and increasing procurement lead times, the Navy is actively pursuing flexible computer integrated manufacturing (FCIM) technologies, integrated by communication networks to respond rapidly to its requirements for parts. The Rapid Acquisition of Manufactured Parts (RAMP) program, initiated in 1986, is an integral part of this effort. The South Carolina Research Authority (SCRA) is the prime contractor to the Naval Supply Systems Command (NAVSUP) on the RAMP effort, with Arthur D. Little, Battelle, Grumman Data Systems, and SEACOR major subcontractors. The RAMP program's goal is to reduce the current average production lead times experienced by the Navy's inventory control points by a factor of 90 percent.

To achieve that goal, RAMP must possess sufficient flexibility and adaptability to cope with production demands involving a variety of parts and a range of part families. RAMP's ability to perform rests largely on its integration of commercially available off-the-shelf software products, and its use of product definition data known as PDES--Product Data Exchange using STEP. (STEP, for STandard for the Exchange of Product model data, is the international standard being developed to allow the transmittal of product data between heterogeneous CAD/CAE/CAM/CIM platforms. PDES is the U.S. activity responsible for the implementation and acceptance of STEP in this country.) A PDES file for a part will contain a 100% complete, unambiguous, computer-interpretable description of the physical <u>and</u> functional characteristics of that part. The RAMP system architecture enables the receipt, storage, and use of electronic data conforming to PDES, most notably for accomplishing automated process planning.

The manufacturing engineering component of the RAMP architecture utilizes an intelligent processing technology built around a knowledge-based shell provided by ICAD, Inc. Rules and data bases in the software simulate an expert manufacturing planner's knowledge of shop processes and equipment. This expert system can use PDES data to determine what features the required part has, what material is required to manufacture it, what machines and tools are needed, and how the part should be held (fixtured) for machining, among other factors. The program's rule base then indicates, for example, how to make each feature, in what order to make it, and to which machines on the shop floor the part should be routed for processing. This information becomes part of the shop work order. The process planning function under RAMP greatly reduces the time and effort required to complete a process plan, and since the PDES file that drives the intelligent processing is 100% complete and accurate to start with, the potential for costly errors is greatly diminished.

The RAMP architecture has been configured to support the requirements of the large defense industrial facilities--shipyards, arsenals, depots, etc. However, the majority of spare parts suppliers to the Department of Defense are small manufacturers. For that reason, in 1990 NAVSUP tasked the SCRA to initiate a case study whereby a subset of the RAMP technology would be integrated into a small company's manufacturing operation in order to evaluate the technology's benefits and shortcomings, and to determine how the architecture might be "repackaged" for the small manufacturer. The Federal Emergency Management Agency (FEMA), along with the Defense Logistics Agency, contributed funding to this effort. FEMA's interest lies in the ability of the country's industrial base to support mobilization activities, either in support of wartime requirements, or in the event of natural disaster.

After a competitive solicitation, *In Tolerance,* a subsidiary of the Norman Scott Company located in Cedar Rapids, Iowa, was selected to be the case study company in April 1991, under a cost sharing arrangement with the government. The project was soon thereafter designated PRISM--Prototype RAMP Implementation in Small Manufacturing. The subset of the RAMP architecture, designated the PRISM system, installed at *IT's* factory consists of a SUN Sparcstation II on which the ICAD process planning software is running, along with ComputerVision's CAD software (CADDS-4X), Oracle's relational data base management software, and the applicable RAMP-developed software modules required to adapt the system to *IT's* operati on .

The PRISM system configuration will enable *IT* to receive and store PDES data for required spare parts, and to then generate from that PDES data IGES (Initial Graphics Exchange Specification) representations of those parts for use by *IT's* existing CAM system (where tool path instructions are developed). In addition, the PRISM system will output a hard-copy engineering drawing of the part, again generated from the PDES data, that can be used by *IT's* shopfloor personnel and DoD quality inspection representatives. Finally, the PRISM system will generate a process plan for each part from its associated PDES file. Each plan will provide the recommended routing for the manufacture of the required part, as well as a bill of materials. *In Tolerance* will then input the process and material information generated by the PRISM system into its existing Automated Quoting, Inventory, and Scheduling system (AQUISS) in order to develop the quote and delivery estimates for each part. This retained process information is then available for manufacture upon receipt of order.

To evaluate the effectiveness of RAMP technology within the small manufacturer, a total of ten orders for spare parts will be issued from DLA's Defense Construction Supply Center--five containing PDES data describing the required parts, the other five containing only conventional technical data packages (paper). Data will then be collected and analyzed to determine the accuracy and timeliness of *IT's* quoting and manufacturing processes when supported with the RAMP technology (using PDES data as an input), and to compare those results with the results obtained when *IT's* conventional quoting and manufacturing practices are used (with paper as an input). This evaluation is scheduled to be completed in March 1992.

Once the results of the PRISM project have been recorded and reviewed by the Navy, FEMA, DLA, SCRA, and *In Tolerance,* a decision will be made regarding what, if any, follow-on activity will be conducted to leverage the "lessons learned" from the year-long case study.

PROTOTYPE RAMP IMPLEMENTATION IN SMALL MANUFACTURING (PRISM)

The purpose of the PRISM Project is to evaluate the potential strategic, economic and performance impact of Rapid Acquisition of Manufactured Parts (RAMP)/Product Data Exchange Using STEP (PDES) technology in small defense-related manufacturing to improve industrial capability and competitiveness.

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(803) 760-3241

A Presentation on:

INTELLIGENT PROCESSING
& THE SMALL MANUFACTURER

IPE Conference
3 December 1991

SCRA™

AGENDA

- Product Data Exchange Using Step (PDES)
- Flexible Computer Integrated Manufacturing (FCIM)
- Prototype RAMP Implementation in Small Manufacturing (PRISM)

PDES

PRODUCT DATA EXCHANGE USING STEP

PRODUCT DATA EXCHANGE USING STEP

TODAY'S PROBLEM

TECHNICAL DATA, IF AVAILABLE, IS TYPICALLY:

- Prepared by Various Manufacturing Organizations
- Produced to Different Drawing Standards
- Incomplete (Not Truly Reprocurement Quality)
- Laden with Extraneous Information
- Inaccurate, Not Reflecting the "As Built"
- Paper-Intensive: Cumbersome and often Illegible

PDES

PRODUCT DATA EXCHANGE USING STEP

THE PROPOSED SOLUTION: PDES

1984: Develop a standard, to be accepted both nationally and internationally, that will provide:

"A complete, unambiguous, neutral, computer-interpretable definition of the physical and functional characteristics of a product through its complete life cycle."

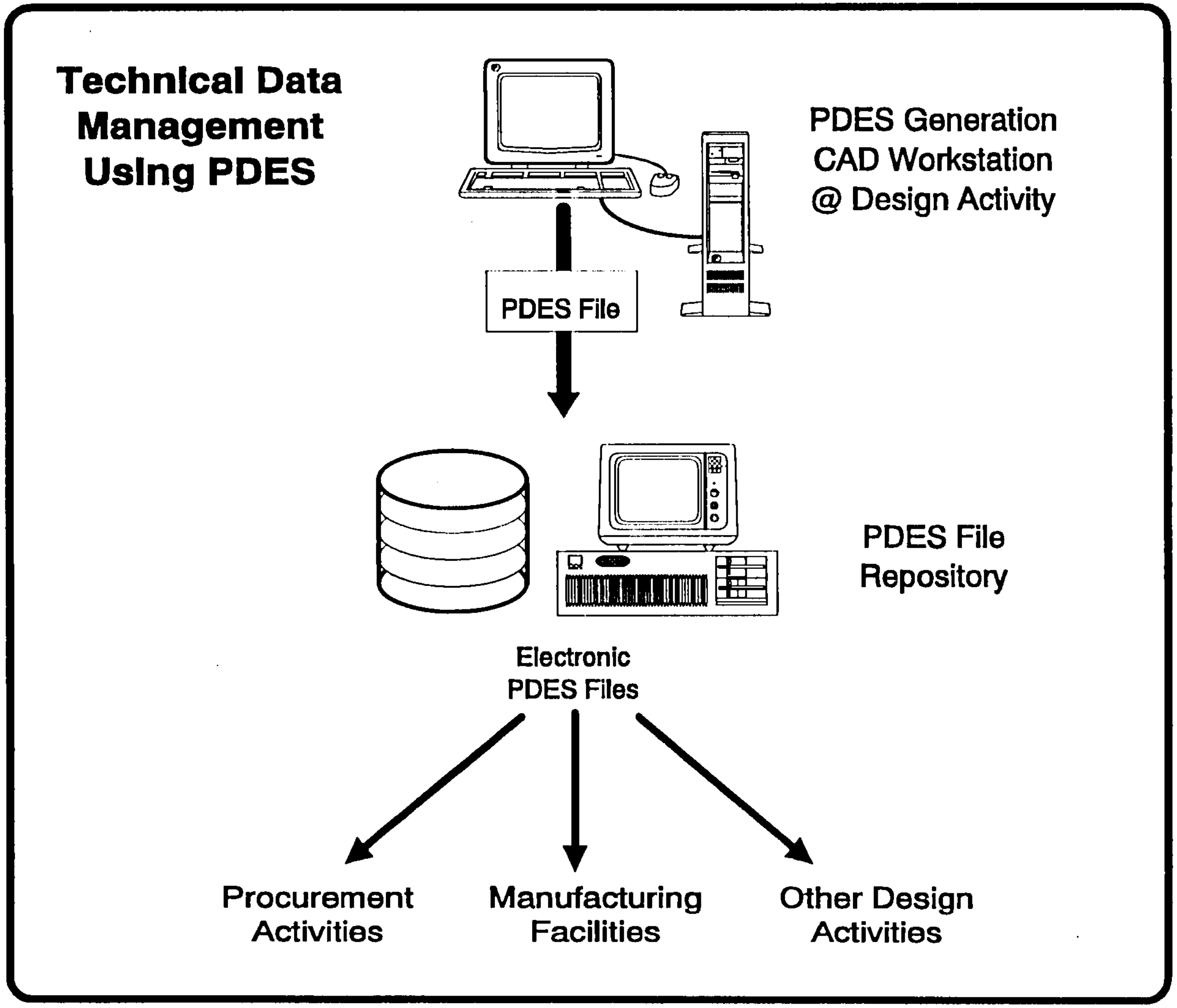
Initially designated Product Data Exchange Specification, now the Product Data Exchange using STEP - PDES. (STEP is the international STandard for the Exchange of Product model data.)

RAPID ACQUISITION OF MANUFACTURED PARTS - RAMP

THE RAMP FCIM TECHNOLOGY

- Completely Integrates Planning, Engineering, Quality, and Manufacturing → CALS-Compatible
- Manufactures a High Volume, High Mix of Parts Concurrently (But also Support High Volume, Low Mix Production)
- Can Use an Electronic Input (e.g., PDES)
- Manufactures Parts on Demand Within 30 Days (Average) of Receipt of Order

PRODUCT DATA EXCHANGE USING STEP



PRODUCT DATA EXCHANGE USING STEP

PDES: FACT AND FICTION

PDES IS:

- A Standard Representation of Product Data, providing a 100% Complete Definition of What the Product is
- A Prime Element of the DoD CALS Initiative
- Implementable by Application (e.g., Mechanical)
- Automation enabling for Flexible Computer Integrated Manufacturing

PRODUCT DATA EXCHANGE USING STEP

PDES: FACT AND FICTION

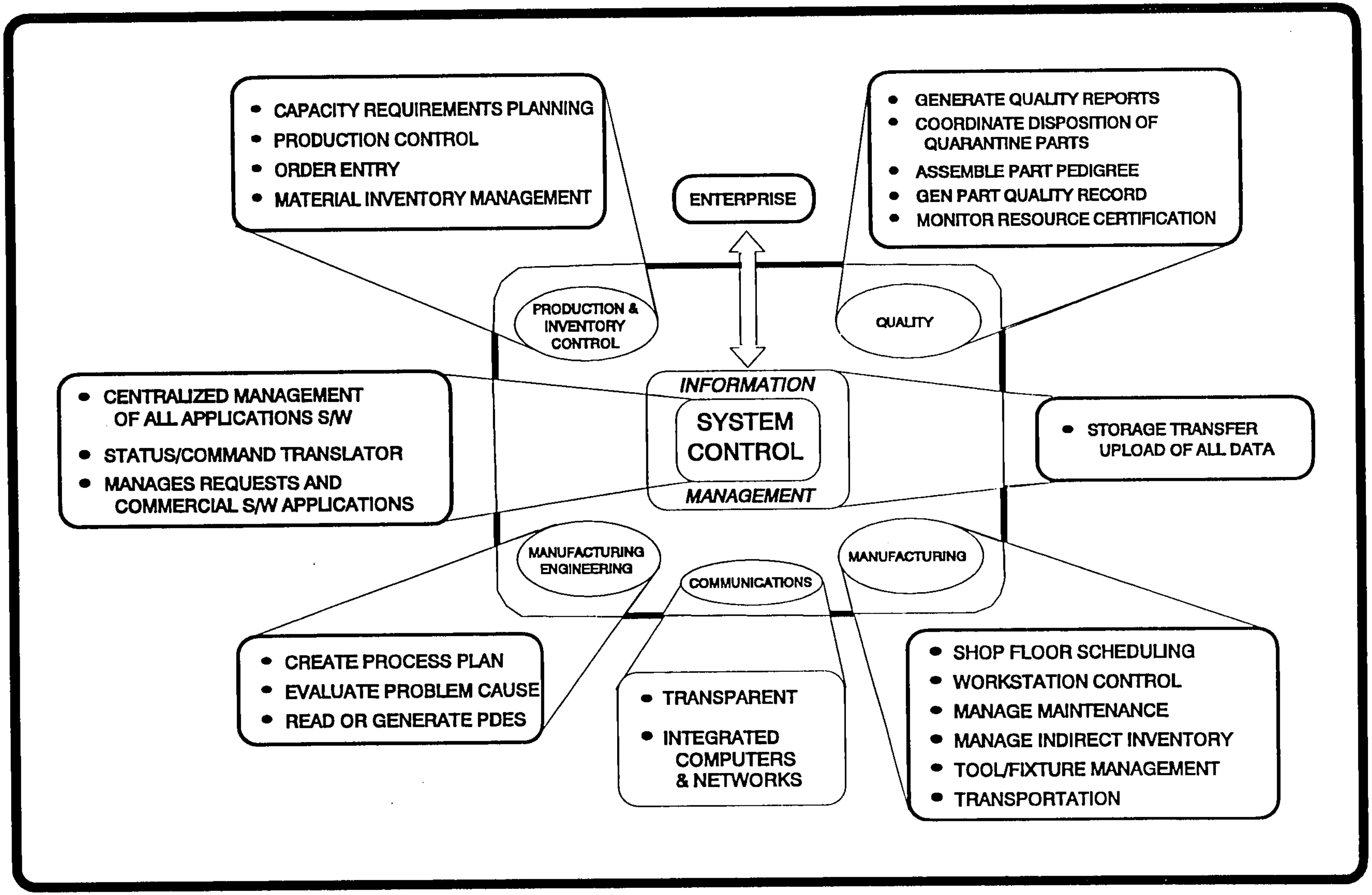
PDES IS NOT:

- "Next-Generation IGES" or "IGES++"
- A Description of How the Product is to be Made - There is No Process Information
- Available yet for Full Implementation
- The Answer to all Technical Data Problems
- Fully Stable

CALS

FCIM

RAMP FCIM ARCHITECTURE



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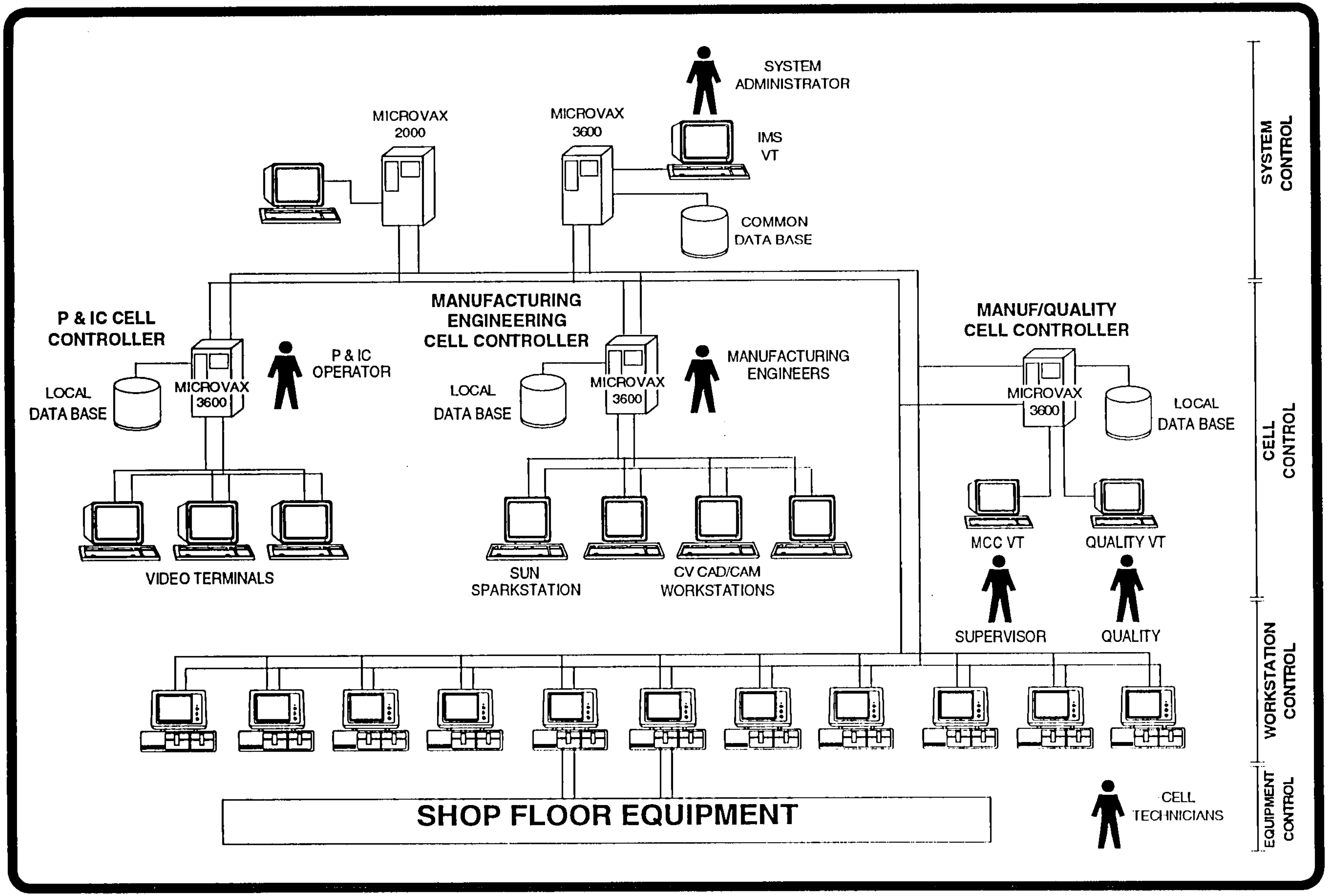
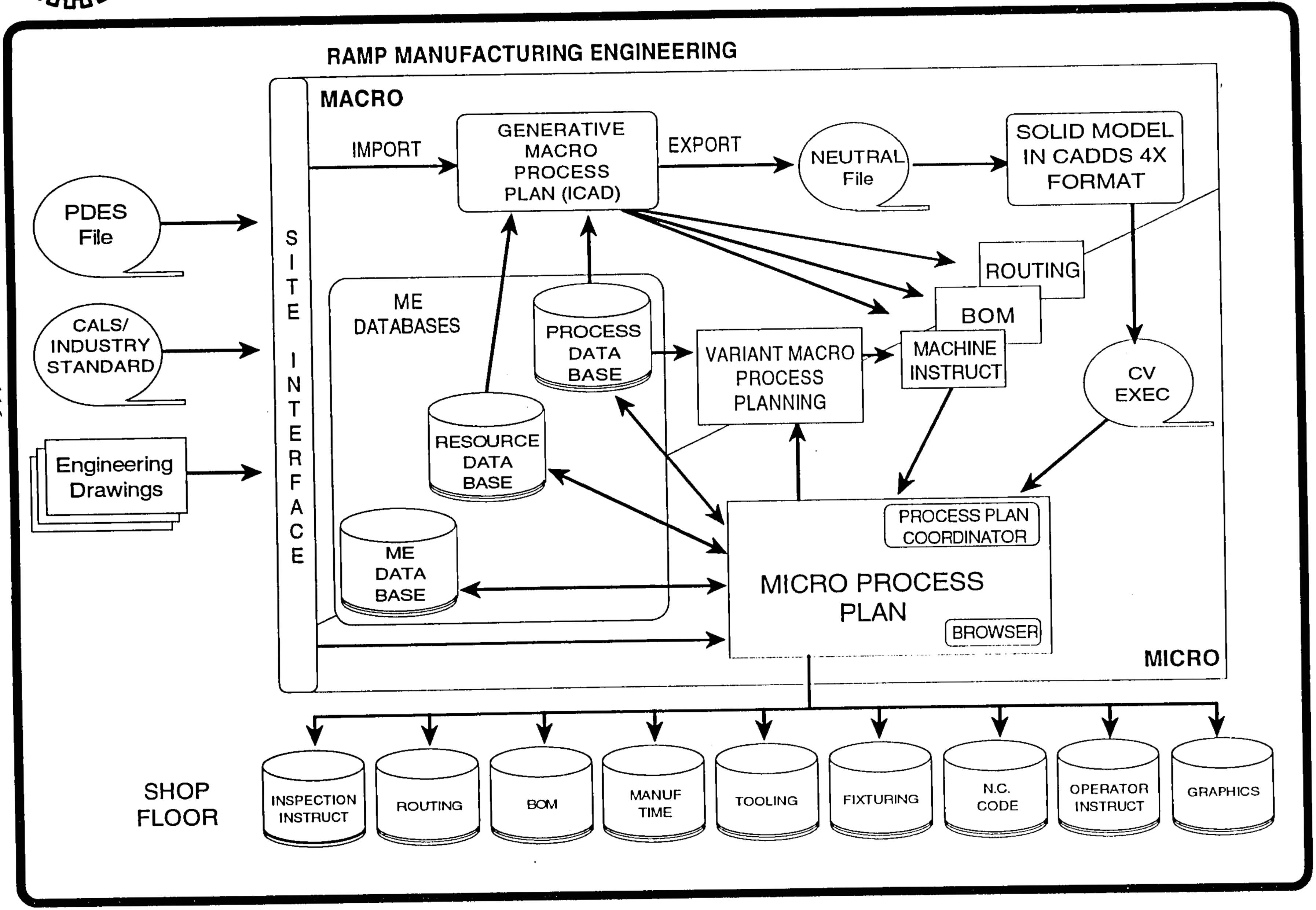
RAMP FCIM ARCHITECTURE (SMP)



RAMP FCIM ARCHITECTURE (SMP)



PRISM

**PROTOTYPE RAMP IMPLEMENTATION
IN SMALL MANUFACTURING**

SMALL BUSINESS CASE STUDY GOAL

GOAL OF STUDY:

EVALUATE THE POTENTIAL STRATEGIC, ECONOMIC, AND PERFORMANCE IMPACT OF RAMP TECHNOLOGY AND INNOVATIVE TECHNICAL DATA EXCHANGE IN THE OPERATIONAL ENVIRONMENT OF A SMALL DEFENSE-RELATED MANUFACTURER

PRISM

SMALL BUSINESS CASE STUDY

"IN_TOLERANCE" PROFILE

- 25-30 PERSONNEL
- $1.5 MILLION ANNUAL REVENUE
- 20,000 SQ FT SHOP FLOOR
- SIX CNC MACHINES, CMM
- TELEVIDEO PC W/MASTERCAM SOFTWARE
- LIMITED DNC VIA RS-232 LINK
- MIL-I-45208 QUALIFIED
- NOVELL LAN W/CUSTOM AQUISS SOFTWARE
- PRIMARY COSTOMERS: ROCKWELL COLLINS
CIVCO MEDICAL
- EDI LINK VIA COMMERCIAL MAILBOX

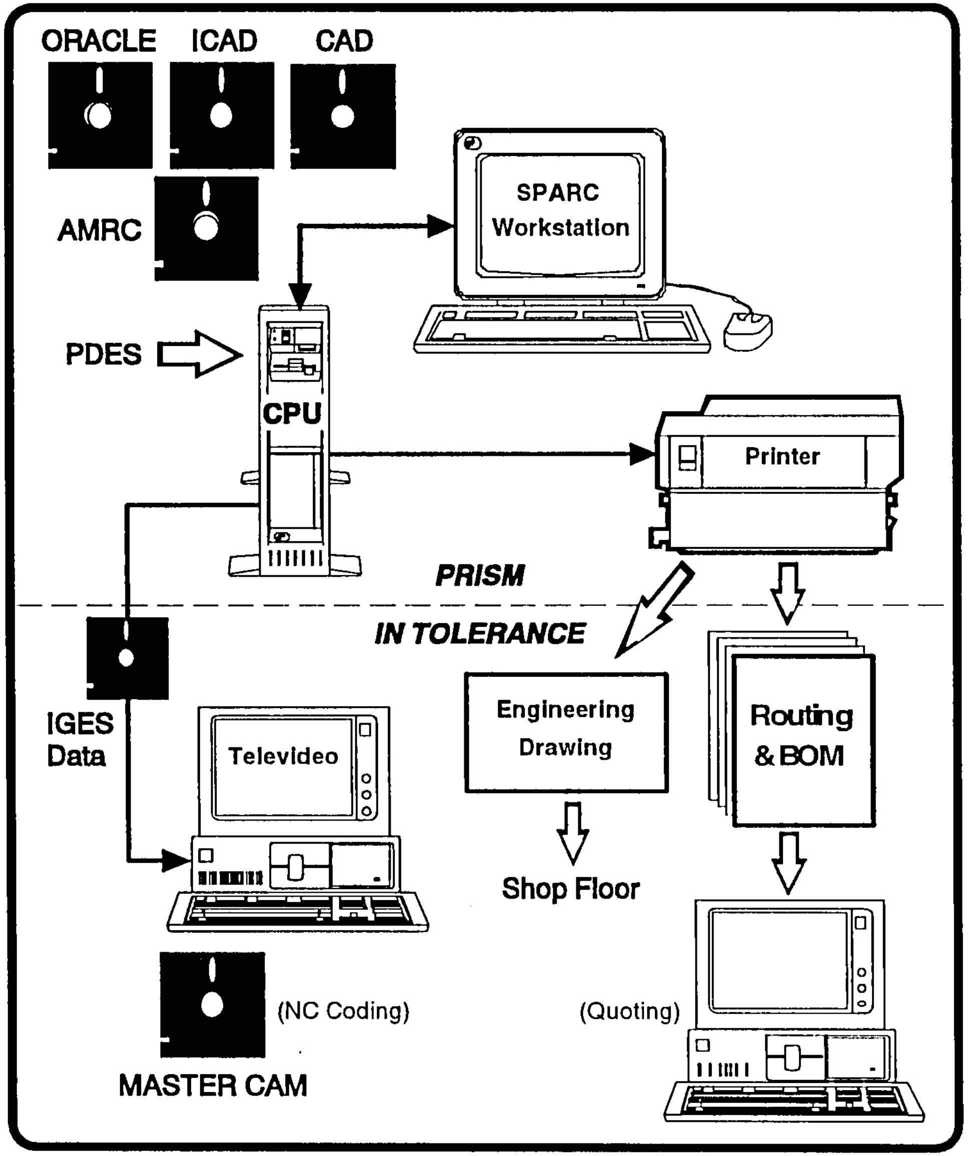
PRISM

SMALL BUSINESS CASE STUDY OBJECTIVES

PARTICIPANTS	PRIMARY OBJECTIVES OF STUDY PARTICIPATION
IN_TOLERANCE	INCREASE COMPETITIVE EDGE
DLA	IMPROVE QUALITY, COST/SCHEDULE EFFECTIVENESS OF SUPPLY BASE
FEMA	ENHANCE INDUSTRIAL MOBILIZATION CAPABILITY
NAVSUP	ENSURE RAMP SUCCESS/TECHNOLOGY TRANSFER

OBJECTIVES ARE STRATEGIC, ECONOMIC, AND PERFORMANCE RELATED

PRISM SYSTEM SOFTWARE AND HARDWARE COMPONENTS



PRISM SYSTEM FUNCTIONS

- PDES INPUT (SUPPORTED FEATURES AS OF 9/1/91)
- ORDER SEQUENCER
- STORE PDES
- INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES) OUTPUT
- GENERATIVE PROCESS PLANNING
- NC JOB CONTROL FILE OUTPUT
- INTERFACE TO CAD/CAM
- ENGINEERING DRAWING REPRESENTATION FROM CV-TRANS

PRISM

OPERATIONAL SCENARIO

- RECEIVE PDES FILES FROM DLA
- PDES FILES CONTAIN PARTS THAT CONFORM TO SEVEN FEATURE CLASSIFICATIONS
  - CIRCULAR FACE
  - OUTER DIAMETER
  - INNER DIAMETER
  - THROUGH HOLE
  - INTERIOR CIRCULAR CHAMFER
  - EXTERIOR CIRCULAR CHAMFER
  - EXTERNAL THREADS
- LOAD PDES FILES INTO DATABASE
- PROCESS PDES TO CREATE ROUTING, BOM AND PIF
- UTILIZE INFORMATION ABOUT:
  - SIX CNC MACHINES
  - ANCILLARY PROCESSES
- CREATE IGES FILE FOR MASTERCAM
- CREATE ANNOTATED ENGINEERING DRAWINGS

PRISM PROJECT FOCUS

- PRISM PROJECT PROVIDES A UNIQUE OPPORTUNITY FOR ASSESSMENT OF RAMP/PDES TECHNOLOGIES IN A REAL WORLD SMALL BUSINESS APPLICATION.

- EVALUATION WILL FOCUS ON THE IMPACT OF RAMP/PDES TECHNOLOGY ON THE DEFENSE SUPPLY BASE, INDUSTRIAL MOBILIZATION, AND COMPETITIVE EDGE OF SMALL MANUFACTURERS.

- FINAL EVALUATION REPORT DUE TO BE COMPLETED APR 92.

ASSESSMENT OF INTELLIGENT PROCESSING EQUIPMENT IN THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION 1991

by

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Huntsville, AL 35812

ABSTRACT

During September and October, 1991, an assessment of activities within the National Aeronautics and Space Administration relating to "Intelligent Processing Equipment (IPE)" was conducted. In this assessment, research and development activities that related to IPE were surveyed for work being conducted by NASA or contractors funded by NASA. A compilation of project submittals is included as an appendix.

This report summarizes the assessment of intelligent processing equipment within NASA. It attempts to determine the state of IPE development and research in specific areas where NASA might contribute to the national capability. Finally, mechanisms to transfer NASA technology to the U.S. private sector in this critical area are discussed.

INTRODUCTION

In March, 1991, the National Critical Technologies Panel, organized by the Executive Office of Science and Technology Policy, reported to the president on 22 technologies critical to the nation's future in light of global competition. Four of these technologies, dealing with advanced manufacturing, were assigned to an inter-agency advanced manufacturing steering group, chaired by the deputy NASA administrator, J. R. Thompson. These advanced manufacturing technologies are listed as follows:

Intelligent Processing Equipment
Flexible Computer Integrated Manufacturing
Micro and Nanofabrication
Systems Management Technologies

The group decided to initiate a pilot effort to collect all technology related to one of the four, intelligent processing equipment (IPE), from on-going development efforts and present this collected information to industry before the end of 1991. In June, 1991, the steering group asked R. J. Schwinghamer of NASA to chair a task team consisting of members from nine participating government agencies and to plan and execute this task in the short time permitted.

The IPE task team decided that the briefing to industry would be combined with a previously planned NASA conference, Technology 2001, on December 3-5, 1991. The IPE conference sessions were added to the Technology 2001 program, and consist of presentations of the agency assessments and panel discussions. The panel discussions are grouped in the three major IPE categories; robots, sensors and controls. As a result of the interchange, the inventory of Federal advanced manufacturing-related R&D activities should provide an awareness among industry participants of some technologies available for transfer to the private sector. The panel discussions will serve as a forum for input to what the government can do to improve private use of federal research efforts in the area of intelligent processing equipment.

After the IPE conference, the organizers will publish the government presenter's papers and the proceedings of the industry panel discussions.

NASA-WIDE ASSESSMENT

The assessment of NASA technology activities relating to intelligent processing equipment was conducted between August 1 and November 1, 1991. A copy of all inputs of NASA technology to the assesment is included as an appendix.

Since "intelligent processing equipment" is a term not normally used in technical interchange at NASA, a simple keyword search of published papers would not provide the necessary information. It was decided that a pro-active approach would be required to find current activities relating to this subject. An eight-member assessment team was formed at the Marshall Space Flight Center to make contacts with researchers that might be working with intelligent processing equipment. These contacts included submitters to the annual "Research and Technology Report" of the Marshall Space Flight Center, and principal investigators for major research and technology programs. Meetings were held with the chief engineers of all programs to determine if any work was being conducted by prime or sub-contractors that would apply. The MSFC team also selected major laboratories within the Center that were working in areas applicable to IPE. The directors of these labs were briefed and asked to provide a list of contacts within their labs that could contribute. Finally, the heads of the science and engineering directorate at each NASA center were asked to provide a prime contact to coordinate the assessment for that center, in a similar fashion.

To effect the assessment, a survey form created by the government-wide IPE task team was used to collect the information. This form was sent to each contact, along with an introductory letter by the NASA coordinator, instructions on how to fill out the form, the definition of IPE, and a newspaper article with some background information. The input form was then filled out by each respondent and forwarded to the NASA agency-wide coordinator at MSFC. The information from each form was entered into a computer database at MSFC. A copy of the assessment form is shown in Figure 1.

CIT Advanced Manufacturing
Intelligent Processing Equipment
Project Description Form

1. TITLE:

2. ORGANIZATION/CONTACT:

3. a. FUNDING SOURCES: _ Federal Gov't _ State-Local Gov't
_ Industry _ University _Other

b. PARTICIPANTS: _ Federal Gov't _ State-Local Gov't
_ Industry _ University _Other

c. OPERATING MODE: _ Contract _ Grant _ CRADA _ Internal
_ Other

4. DESCRIPTION:
a. Scope:
(1) Year Initiated ____________

(2) Project Funding Level
(Total, Estimate): _ < $50K _ $50K - $200K
_ $201K - $500K _ > $500K

b. Project Summary:

5. MAJOR CATEGORY:

_Robotics _ Sensors _ Controls

6. GOALS:

Improve: _ Capability _ Quality _ Efficiency

7. POTENTIAL APPLICATION(S):
_ Aerospace _ Agriculture _Automobile _ Chemical
_ Communication _ Computer _ Construction _ Health Care
_ Mining _ Petroleum _ Pharmaceutical _ Other_________

Figure 1 - Project Description Form

ASSESSMENT RESULTS

By the end of the assessment period, 248 responses had been received. Inputs came from NASA's field centers and laboratories.

The projects described in the responses were categorized as shown in figure 2:

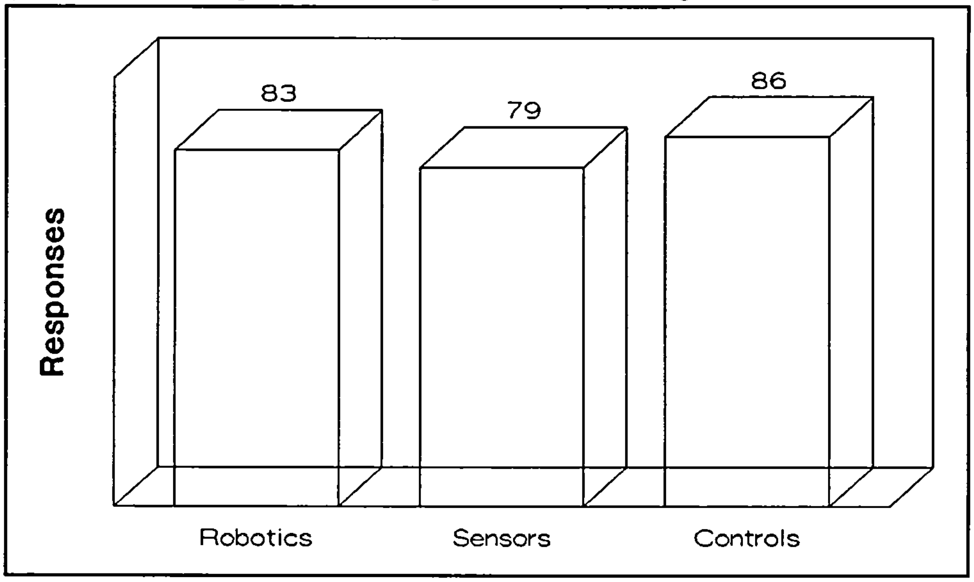

Figure 2 - Responses by Major Category

Most funding for these projects came from federal sources exclusively, but some utilized funding contributions from industry or other sources as shown in figure 3.

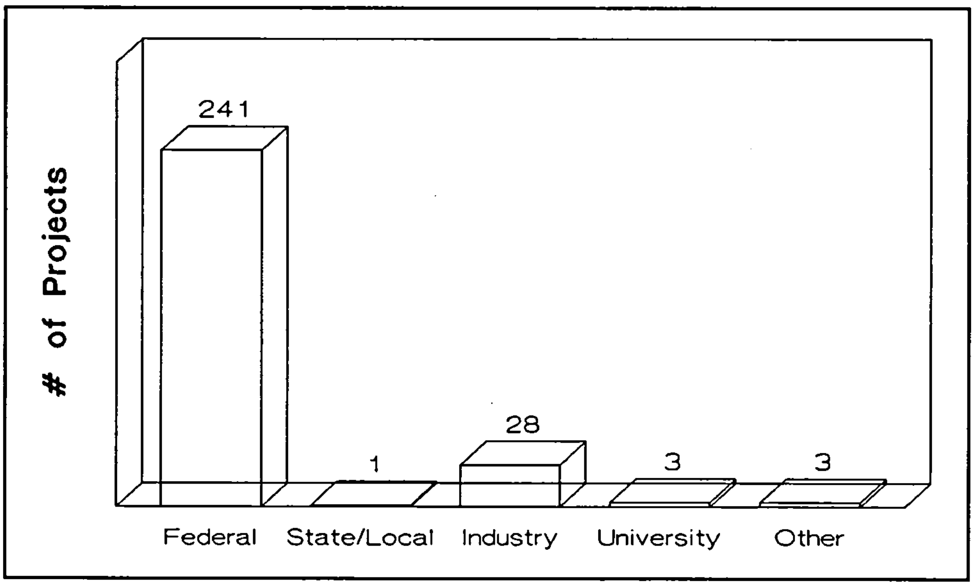

Figure 3 - Funding Sources

The projects had a variety of participants, but most utilize NASA and Industry in cooperation, as shown in the chart in figure 4. Another large contributor of participants was universities.

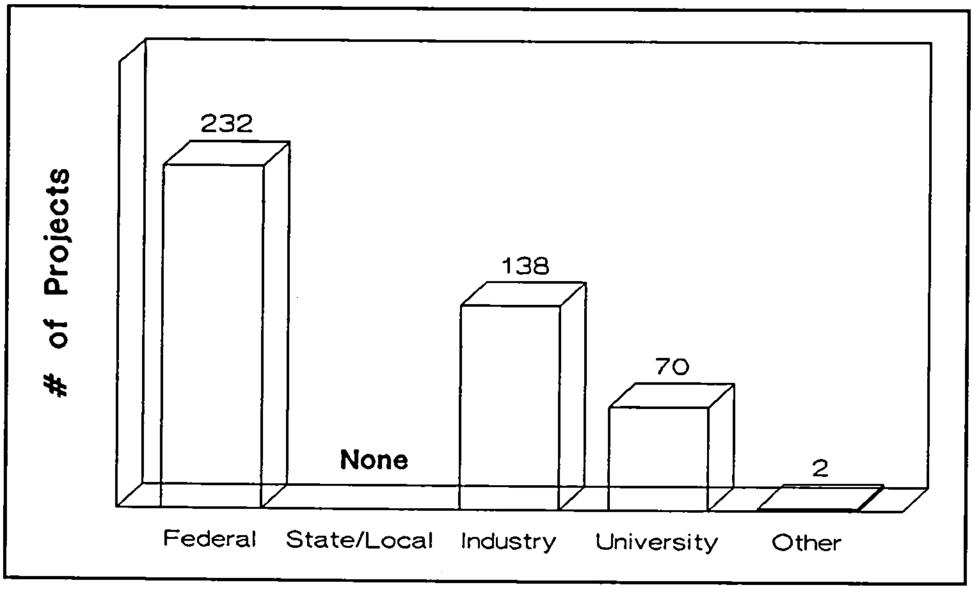

Figure 4 - Breakdown of Participants

The majority of projects operated through direct government contracting, but many utilized NASA internal laboratories or Cooperative Research and Development Agreements (CRADA's).

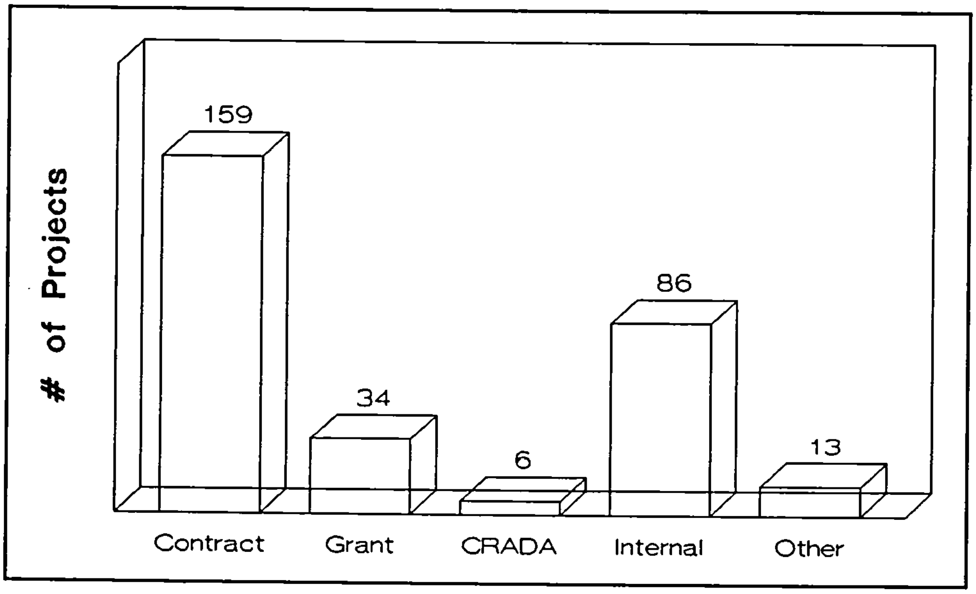

Figure 5 - Operating Mode

The majority of projects have begun within the last 5 years, indicating that most reported work is current. The distribution of lengths is shown in figure 6:

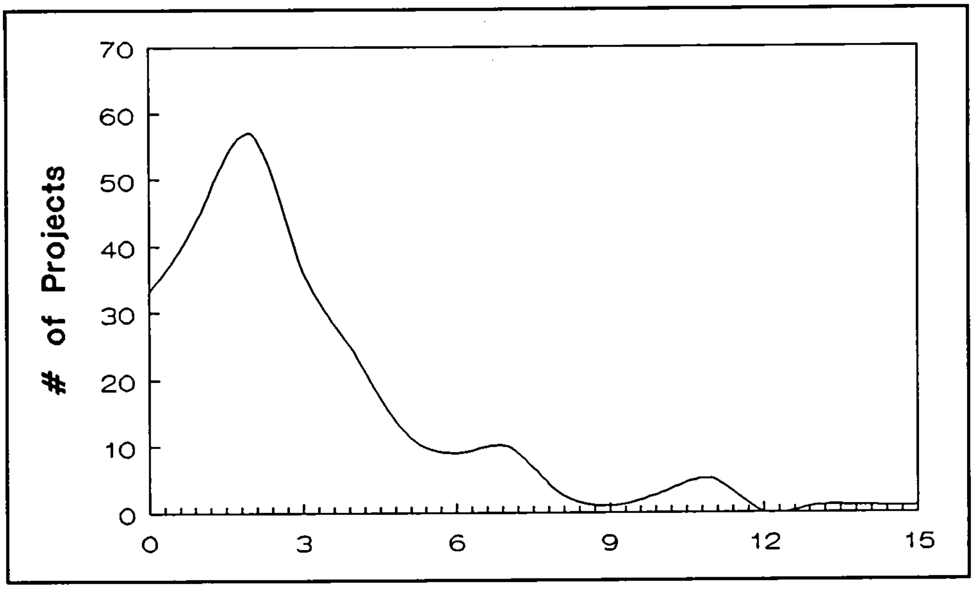

Figure 6 - Project Length

Total project funding levels were distributed between all four funding levels that could be chosen, as shown in figure 7:

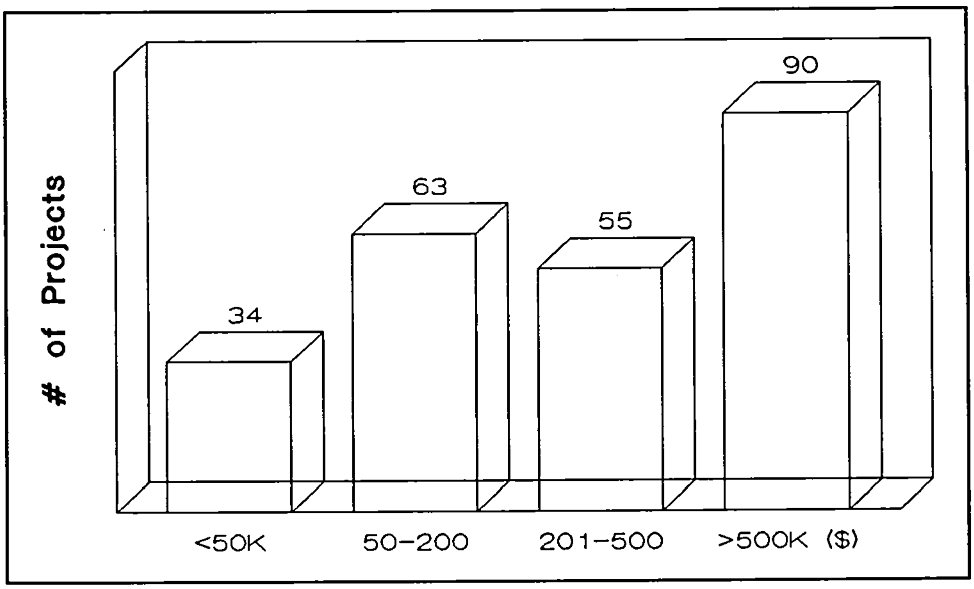

Figure 7 - Breakdown of Funding Level

The stated goals of the submitted projects were categorized into three areas, which are shown in figure 8. The responders could select more than one goal category.

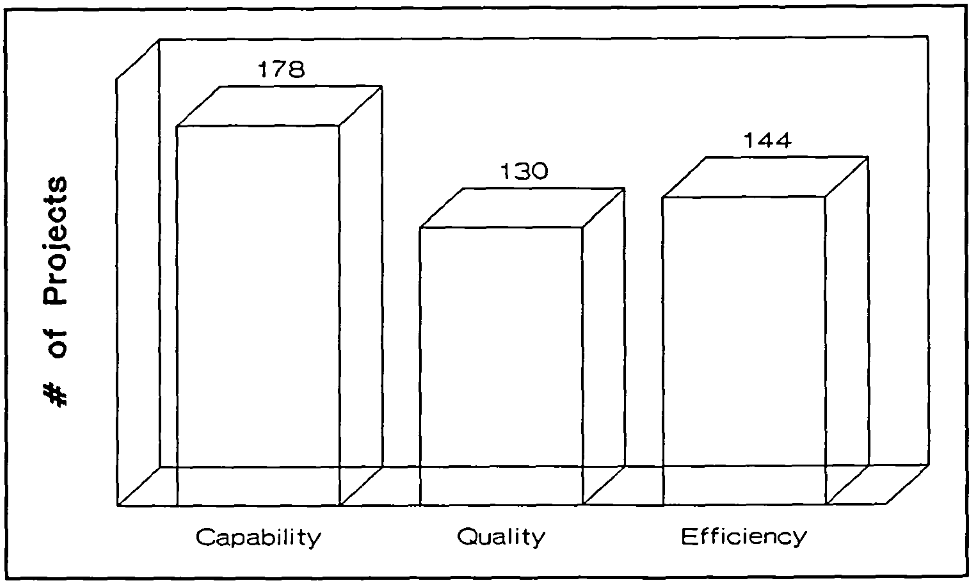

Figure 8 - Breakdown of Goals

The project contacts were asked to pick some potential applications for their technology . The applications cited are shown in figure 9. Most projects cited applications to the Aerospace, Automobile, Chemical, Construction, and Petroleum industries.

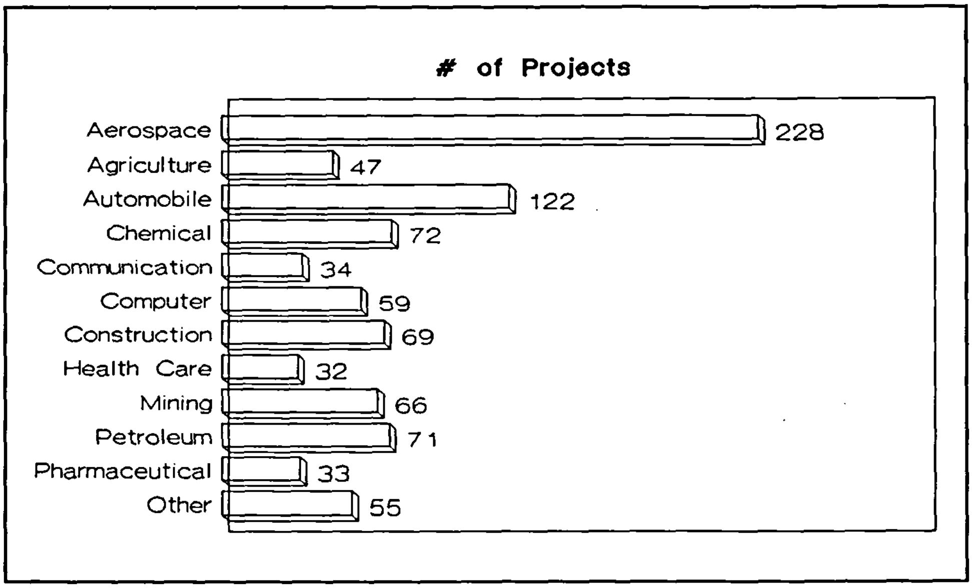

Figure 9 - Potential Applications

An often-cited application in the "Other" category was the Nuclear industry.

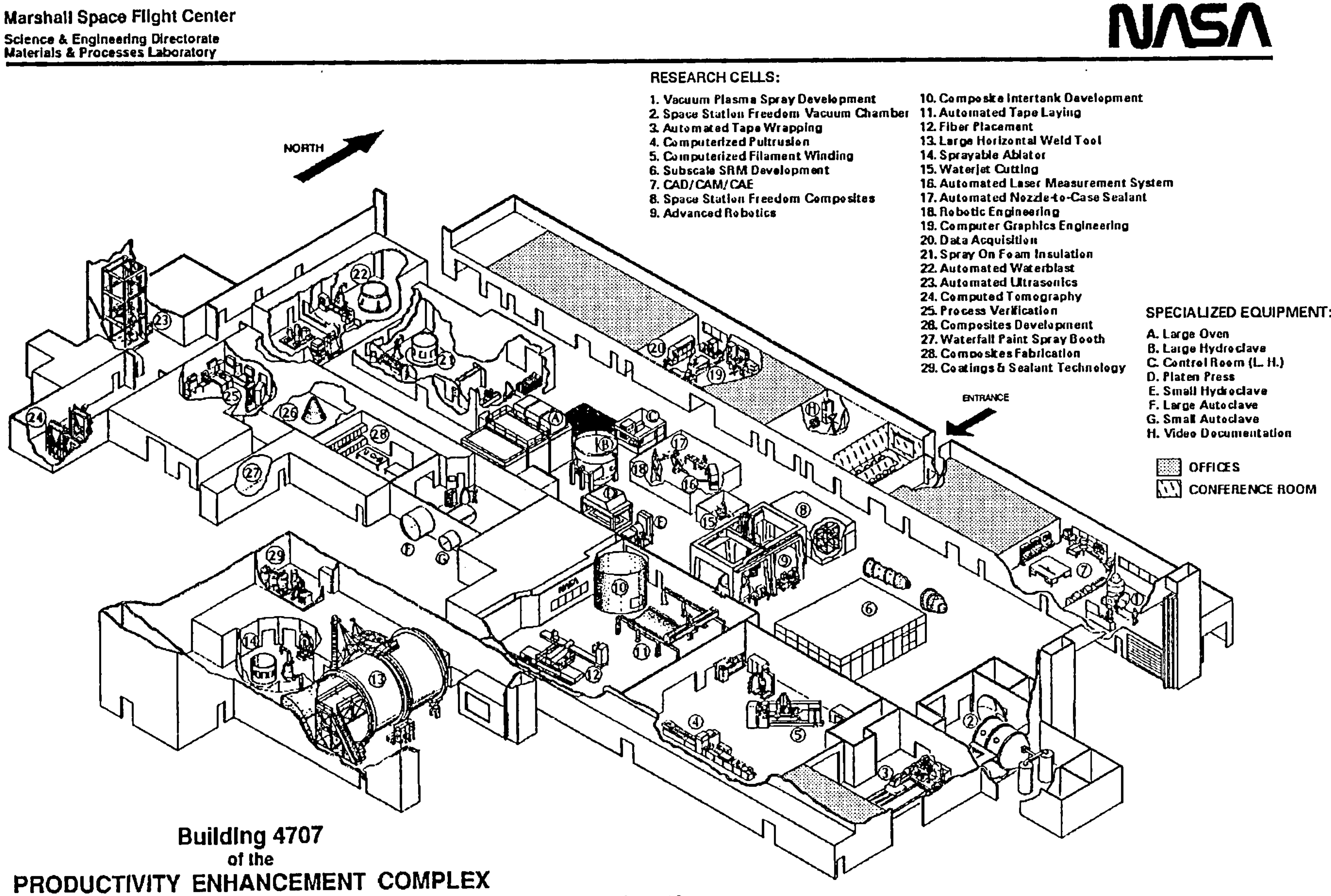
Marshall Space Flight Center
Science & Engineering Directorate
Materials & Processes Laboratory
NASA
NORTH
RESEARCH CELLS:
1. Vacuum Plasma Spray Development
2. Space Station Freedom Vacuum Chamber
3. Automated Tape Wrapping
4. Computerized Pultrusion
5. Computerized Filament Winding
6. Subscale SRM Development
7. CAD/CAM/CAE
8. Space Station Freedom Composites
9. Advanced Robotics
10. Composite Intertank Development
11. Automated Tape Laying
12. Fiber Placement
13. Large Horizontal Weld Tool
14. Sprayable Ablator
15. Waterjet Cutting
16. Automated Laser Measurement System
17. Automated Nozzle-to-Case Sealant
18. Robotic Engineering
19. Computer Graphics Engineering
20. Data Acquisition
21. Spray On Foam Insulation
22. Automated Waterblast
23. Automated Ultrasonics
24. Computed Tomography
25. Process Verification
26. Composites Development
27. Waterfall Paint Spray Booth
28. Composites Fabrication
29. Coatings & Sealant Technology
SPECIALIZED EQUIPMENT:
A. Large Oven
B. Large Hydroclave
C. Control Room (L. H.)
D. Platen Press
E. Small Hydroclave
F. Large Autoclave
G. Small Autoclave
H. Video Documentation
OFFICES
CONFERENCE ROOM
ENTRANCE
Building 4707
of the
PRODUCTIVITY ENHANCEMENT COMPLEX

Figure 10

SUMMARY

While more than 240 different projects related to IPE have been submitted, approximately 100 projects appear to be specifically targeted towards manufacturing processes. The remainder are technologies relating to robots, sensors, or controls that have potential application to intelligent processing equipment in manufacturing.

A large proportion of the projects targeted towards manufacturing relate to processing and refurbishment of the space shuttle's solid rocket boosters, including technology planned for implementation in the new advanced solid rocket motor manufacturing facility in Iuka, Mississippi. Welding for the shuttle main engines, external tank, and the space station Freedom employs elements of IPE in current production equipment. Application of cryogenic foam material to the external tank is in the process of implementing more advanced process control equipment. Significant developments in robotics are under-way for application to robotic assembly of structural elements in space.

The closest NASA comes to common commercial manufacturing, however, is in the construction of the components of the Space Shuttle. A new external fuel tank must be built for each mission, and the solid rocket boosters must be refurbished and loaded with propellant. While the three main engines of the orbiters are reused, different components must be replaced varying intervals, resulting in requirements for approximately 3 to 4 equivalent engines to be built each year.

In the past, manufacturing for the space program could be said to follow a craft-based approach. Each component for each mission is built individually, with most parts made to fit for each application. Skilled craftsmen were required to control the process to the requisite quality level, with extensive inspections required to assure flight readiness.

Productivity Enhancement Complex

In order to support a shuttle flight rate of 6 to 12 flights per year, however, it was determined that intensive development of improved manufacturing processes would be required. For this purpose, NASA created the Productivity Enhancement complex in 1981. The primary objectives are the development of advanced materials and manufacturing methods focused on real needs in MSFC-contracted programs. A layout of the main building in the Productivity Enhancement complex is shown in figure 10. The listing of development cells gives an indication of the broad scope of activities under-way in the complex.

At the Productivity Enhancement Complex, NASA and contractor engineers share laboratory facilities to develop and qualify new manufacturing processes off-line from flight hardware production. The common laboratories allow cross-pollination of ideas between programs, and eliminate duplication of facilities. New processing ideas can be demonstrated and qualified without interruption of the production schedule. This approach provides incentives to the incorporation of new ideas, and fosters an environment for continuous improvement.

The normal approach for process development in the Productivity Enhancement complex begins with an acknowledged need in a specific component, such as reduction of serial flow time in refurbishment, or reduction of welding rework. Once a technology has been identified to address the need, a joint team is formed between NASA and the affected prime contractor to perform a concept demonstration. The successful demonstration of the new manufacturing process on simulated flight hardware usually signals the beginning of process qualification for use on flight hardware and integration into the prime contractor's production facility. During this phase, the role of NASA personnel is gradually reduced, and manpower of the contractor increased. This generally smoothes integration of the technology into the contractor's plant, since the contractor is more familiar with production details.

Extremely encouraging results have been achieved in the development of MSFC's spray-able ablator and application process for the solid rocket boosters; automated spray cryogenic foam application processes for the external tank; variable polarity plasma arc welding for aluminum structures; sensor-controlled robotic welding for space shuttle main engines; and fully automated systems for removing thermal protection systems and refurbishment of solid rocket booster hardware after water recovery.

Application Highlights

In each of the aforementioned applications, intelligent processing equipment is critical to the successful introduction of improved technology. Every critical process parameter is under computer control, and robots are used to provide precise motion control while maintaining flexibility in the paths that can be followed. In each case, the processes have evolved to the point that they can no longer be considered simply automation of a previously manual process, but the controls and manipulators operate to a degree of synchronization that cannot be attained by humans. The result is a level of consistency of properties that produces improved quality hardware with less rework, hence reducing total costs.

In the case of robotic welding for the space shuttle main engines, two sensors have been qualified for production. A thru-the-torch vision system provides precise seam following while an advanced signal processing system adjusts weld current to maintain constant penetration for gas-tungsten arc welding. Similar systems for control of variable polarity plasma arc welding have been developed and are presently undergoing qualification testing. A comprehensive theoretical weld model is under development for more complete feedback control of the welding process in the future. A block diagram of the weld penetration control system is shown in figure 11.

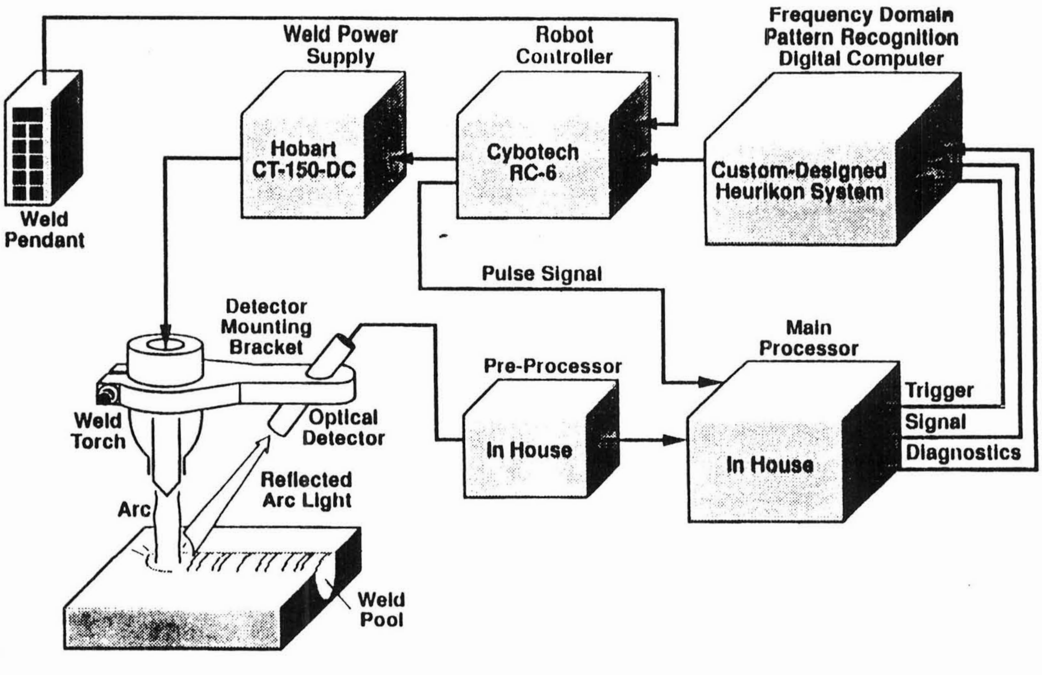

Figure 11 - Major Elements of the Optical Weld Penetration Control System

In the application of foam and ablative insulation materials, extensive use is made of computers in the mixing and dispensing of the insulation's constituents. Sensors are also under development to measure foam thickness in real-time through the use of structured light systems, allowing in-process control.

A "smart" robotic end-effector has been developed for inspection of rocket motor cases for contamination. In this application, a set of ultrasonic distance transducers are coupled with a three-axis manipulator to maintain precise distance and orientation of an ultraviolet contamination scanning sensor. The end-effector is attached to a lead-screw type manipulator that indexes the scanner over the surface of the booster. The result is a computer "map" of the contamination levels, used for a subsequent cleaning operation.

Projects under development in the productivity enhancement complex for future implementation will likely require even more advanced intelligent processing equipment for control. These include:

Vacuum-plasma spray process for construction of metallic components used in LOX/Hydrogen engine main combustion chambers

Ablative and foam insulating materials with water-based solvents and propellants for reducing environmental impact

Improved sensor control of variable polarity plasma arc welding for the shuttle external tank and space station Freedom programs

Technology Transfer

Transfer of IPE technology to the private sector can be accomplished in a variety of ways. Information regarding any of the projects submitted for this assessment can be attained through the identified individual for the project of interest listed in the appendix. Inquiries of a more general nature can be handled through the Technology Utilization office at NASA, where an appropriate point of contact can be furnished for a specific subject area. The actual transfer of technology can be handled through:

Forwarding of information such as drawings or reports through the mail

Meetings with knowledgeable NASA personnel to address a specific problem or question

Site visit by NASA personnel to provide solutions to a specific manufacturing issue

Technology concept demonstration program, through cooperative funding agreement

Cooperative research contract through Small Business Innovation Research contract (SBIR)

Information regarding any of these approaches may be obtained through NASA's Technology Utilization office.

One example of IPE technology transfer has been the development of a seam tracker for welding compressor housings, extracted from sensors developed for the external tank program. Another was the development of a robotic gripper for use in automated plant material processing for greenhouse operations, which was a spin-off of work in developing the smart end-effector for contamination scanning, described above.

CONCLUSIONS

Intelligent processing equipment is finding extensive use in the manufacture of space hardware, especially in the propulsion components of the shuttle. The major benefits are found in improved process consistency, which reduces rework, lowering costs.

Advanced feedback process controls are under development and being implemented gradually into shuttle manufacturing. Implementation is much more extensive in new programs, such as the advanced solid rocket motor and space station Freedom.

The technology from the 248 projects described in the appendix of this report should contribute to improving the nation's manufacturing capabilities and competetiveness. They cover a range of technology areas from non-destructive examination to human life support. Their effectiveness in contributing to advanced manufacturing now depends on the ingenuity of industry in determining potential applications for which the government technical specialists, defined by name and phone number in each project description, are available for additional technical information and discussions.

REFERENCES

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
Synopsis of Project Submissions
Intelligent Processing Equipment

CATEGORY: ROBOTICS

Development of ROBOSIM for Academic/Industrial Use
NASA/MSFC, Mark K. Smith, EB44, (205)544-3813
The goal of this effort is to develop and extend ROBOSIM, a NASA Robotic Simulator software package, to operate within the hardware environment of low-cost graphics workstations for use by industry and the academic community.

Vision Systems for Space Station Applications
NASA/MSFC, Linda Brewster, EB44, (205)544-0169
Research methods in image processing and scene recognition to develop an expert vision system that could be used with robotic systems.

Data Conversion Program for ProtoCAD Printed Circuit Board Fabrication System
NASA/MSFC, Jeff Brown, EB34, (205)544-3720
NASA purchased the ProtoCad printed circuit board generation system. The ProtoCad system requires Gerber graphic data with 3 decimal places accuracy as input.

Compact Video Imaging and Lighting System
NASA/MSFC, Tom Bryan, EB24, (205)544-3550
Develop a compact video imaging and lighting system. The small size of the unit will allow easy integration into robotic end effectors and other applications which require direct vision.

Reconfigurable Work Station
NASA/MSFC, Fred Roe, EB24, (205)544-3512
Developed and patented a design for a reconfigurable work station. The station design incorporates adjustable features that allow the operator to position the station displays and work surfaces for maximum comfort.

Control Electronics Assembly for Automation of a Three-Point Docking Mechanism
NASA/MSFC, J. Montenegro, EB24, (205)544-3514
The control electronics assembly provides automatic control and operation of the Three-Point Docking Mechanisms (TPDM) latches during a docking maneuver. Requirements on the TPDM latches during a docking maneuver are to sense in 3.5 seconds or less, and close latch and preload in 60 seconds or less.

Ultrasonic Inspection of Large Objects (UT)
NASA/MSFC, Ted Kublin ER41, (205)544-8631
Feasibility of using Ultrasonic inspection for large solid rocket motor cases validated. Engineering data obtained on optimized frequency, attenuation, and expected resolution of defects.

Robotics Used in Automated Tape Laying
NASA/MSFC, C. Lester, (205) 544-4804
Automated techniques for layup of composite tape materials are being developed. Originally advanced composite tapes were laid up by hand, ply upon ply, to form laminates. This process was labor intensive and caused inconsistency in the quality of the cured laminates.

Robotic Gas-Tungsten Arc Welding for Aerospace Applications
NASA/MSFC, C. Jones EH42, (205)544-2701
Robotic welding hardware and techniques have been developed as a part of an overall automation effort to improve manufacturing of the Space Shuttle Main Engine. Industrial robots were modified to provide the precise control required.

Automated High-Temperature Sealant Application
NASA/MSFC, Paul Gill/EH44, (205)544-2557
Robotic application of sealant on Solid Rocket Booster (SRB) hardware fasteners is being developed. The current, labor intensive technique consists of hand application of sealant to the hardware and the mixing, loading, and seating of sealant to each of 30,000 fasteners per flight.

Automated Carbon Dioxide Cleaning
NASA/MSFC, David Hoppe, (205) 544-8836
Alternate cleaning techniques are required to reduce the use of chemically hazardous and environmentally debilitating solvents. The use of solidified pellets of carbon dioxide as a blasting media has been investigated and evaluated.

Automated Hydroblast Research Cell
NASA/MSFC, David Hoppe, (205) 544-8836
The automated waterblast research cell provides a quick and safe means for removing a multitude of coatings from various substrates. The automated waterblast system was created to remove the thermal protective system from the retrieved solid rocket motors.

Large Precision Machining Center
NASA/MSFC, Johnnie Clark, (205) 544-2799
A large precision machining system will be used at MSFC in the Engine Research Cell for precision machining of the Space Station Freedom module bulkheads and nodes.

Mobile Robotic Hydroblast System (MRHS)
NASA/MSFC, Majid Babai, (205)544-2795
MRHS was designed and developed to solve problems associated with Solid Rocket Boosters manual refurbishment. This system was developed for automated removal of the Thermal Protection System (TPS) from the Space Shuttle Solid Rocket Boosters prior to disassembly.

Automated Sprayed Ablator Cell
NASA/MSFC, E. Martinez, EH43, (205)544-2724
A fully Automated Sprayed Ablator Research cell has been developed, consisting of robot, turntable, mix and spray equipment controlled and operated by a central supervisory computer. The cell is used to develop and qualify sprayable ablative materials for thermal protection.

Automated Foam Spray Cell
NASA/MSFC, E. Martinez, EH43, (205)544-2724
A fully automated foam spray process development cell has been established. It consists of a GMF S420 Robot, 14 foot air bearing turntable, spray booth environmental control system, foam spray equipment and a data acquisition system controlled and operated from a central computer.

Automated Mix Bowl Cleaning
NASA/MSFC, Ben Powers, EE51, (205)544-5580
Propellant mix bowls are transported to the cleaning facility where they are placed on an automated guided vehicle (AGV). The AGV transports the mix bowl containing residual live propellant to bowl and removes and stores residual excess propellant from the mix bowl.

Solid Rocket Motor Gantry Robot
NASA/MSFC, Ben Powers, EE51, (205)544-5580
A programmable five axis gantry robot system using multiple end effectors to accomplish RSRM case inspection and marking has been procured for the final assembly operations at Thiokol Space Division. The gantry system straddles a 488 inch longitudinal and 60 degree arched surface.

Autonomous Heavy-Work Vehicles
NASA/ARC, Butler Hine, FII, MS 244-4, (415)604-4379
In-situ resource utilization is a component of many lunar base and Mars exploration scenarios. This project would develop an inexpensive full scale research platform for investigating the teleoperation and autonomous operation of a mining vehicle.

Computer Vision for Robotics
NASA/JSC, Robert Goode, ER2, (713)483-2047
The technical objectives of this ongoing project is to provide computerized vision processing to various robotic projects. Areas of technical development include target tracking, identification, position estimation, and detection using video cameras, stereo video cameras, and 3 dimensional laser scanners.

Fuzzy Logic Control of a Robot Balancing of an Inverted Pendulum
NASA/JSC, Laura Webster, ER2,
The project of Fuzzy Logic Control of a Robot balancing an inverted pendulum will provide a platform to: 1) demonstrate the application of fuzzy logic as a tool for real control problems and 2) facilitate the acquisition of a better understanding of fuzzy set theory and fuzzy logic theory.

Self-Organization Via Active Exploration in Robotic Applications
NASA/JSC, Hai Nguyen, ER23, (713)483-9240
This project addresses the issue of how intelligent behavior of a robotic system emerges through active exploration of its environment. A neural net- work model, described as a system of non-linear differential equations, is novelty, reward, and punishment, into a framework from which will emerge competent behavior as the robot interacts with its environment.

Distributed Processing Using Transputers in Robotics
NASA/JSC, Keith Grimm, ER4, (713)483-1532
A distributed processing system based on transputers has been implemented in an autonomous robot known as EVA Retriever. It consists of 14 transputers interconnected via the 20Mhz serial links on the transputer chip.

Reactive Planning for Semi-Autonomous System
NASA/JSC, J. D. Erickson, ER, (713)483-1508
Reactive planning is the ability to adapt to an uncooperative environment and is an essential element of the computational architecture for controlling robotic execution in real world environments. The system architecture plan provides five capabilities essential for reactive response.

Failure Tolerant Manipulator Joint
NASA/JSC, John Chladek, ER4, (713)483-1528
Developed, analyzed, and built a dual motor differential drive servo system for a manipulator joint which can absorb a failure in the mechanism or control system with minimum disturbance on the robot trajectories.

Courier Robot Project/Cybermotion
NASA/JSC, Don Roades, ER4, (713)483-1457
Robotic vehicle that can patrol a prescribed area on a routine schedule. Currently used for delivering mail to several offices.

High Speed Fiber Optic Link for Remote Servo Control
NASA/JSC, Larry Li, (713)483-9160
A fiberoptic link was designed to connect a servo controller with pulse-width modulation output signal and encoder A/B feedback signals to a remote motor-driven circuit. This technology allows for a noise-free servo-loop, long sensor leads, and reduction in the number of wires required by a factor of 16. Automated handshake/protocol was also developed.

Use of Computers to Generate Stereolithography Manufactured Devices and Models
NASA/JSC, J. Humphreys, ER4, (713)483-8968
Stereolithography is a new manufacturing process which is driven by a computer-aided design program. It can be applied to a number of areas where a precision plastic model or device is needed.

External Host Interface for PUMA Robot
NASA/JSC, L. Stokes, ER4, (713)483-8965
Electronic control interface was designed, fabricated, and verified to permit control of a PUMA 560 industrial robot by an external computer host. This enables robot arm commands based on high-level, intelligent software, and external parameters from external sensors.

Virtual Reality System
NASA/JSC, S. Michael Goza, ER4, (713)483-4695
A system has been developed to visualize a simulated computer environment through the use of stereoscopic helmet-mounted displays. The software developed allows multiple simulations to drive a single graphics workstation and the operator to interact with it.

Telerobotics Interconnection Protocol
NASA/JSC, S. Askew, ER4, (713)483-8957
Software which runs on Unix and MS-DOS-based computers which enables remote communication and control of robots over an Ethernet/Internet network link.

EVA Retriever
NASA/JSC, Keith Grimm, (713)483-1532
Supervised autonomous robot that is capable of finding, retrieving, and handing-off tools and equipment to human supervisor under voice control.

Robotic Automated VPPA Weld Scan Tracking and Bead Profiling
NASA/MSFC/Boeing, Waris Jaffery, (205) 461-5313
Development of a real time imaging system to provide mapping of mismatch and peaking on VPPA weld joints and to control the motion path of the robot to track the weld seam.

Organic Nonlinear Optical Material
NASA/MSFC, Frazier, ES74, (205)544-7825
The major goal of this program is to grow high quality thin films and single crystals of nonlinear optical organic material in low gravity. Organic materials are of interest for use in optical systems where the lenses are generally very large.

Hard X-ray/Gamma Ray Imaging Systems
NASA/MSFC, Hoover, ES52, (205)544-7617
Develop Hard X-ray/gamma ray imaging systems using multi-layer coated ultra-smooth mirrors. threat detection at airports, in-situ x-ray analysis during machining and fabrication of metal components.

General Purpose Intelligent Sensor Interface
NASA/MSFC, Robert Crubmley, EB42, (205)544-2624
Development of an expert system for computer user interfaces. Specifically, the determination of what voice processing systems can be interfaced to a LISP machine.

Offline Programming and Simulation for Application to Robotic VPPA Welding
NASA/MSFC/Boeing, Waris Jaffery,(205) 461-5313
Establish the ability to conduct computer programming and machine simulation to verify part programming and tooling restraints prior to downloading to the robot. Allows programming to proceed while production welding continues.

Experimental Rack Allocation System
NASA/KSC, Shannon Potter, CS-GSD-31, (407)867-3526
A knowledge based system that allocates Spacelab experimental racks to missions and slots within missions.

Knowledge-Based Autonomous Test Engineer (KATE)
NASA/KSC, Carrie Parrish, DL-DSD-23, (407)867-3224
KATE is a generic, model-based shell designed to provide autonomous control, monitoring, fault recognition and diagnostics for electrical, mechanical and fluid system domains. KATE incorporates the engineer's reasoning about algorithms.

Tile Cavity Modeling System (SPLASH)
NASA/KSC, Rebecca Welling, LSOC,
The SPLASH tool is a system for measuring the cavity of an Orbiter Thermal Protection System (TPS) tile and outputting data to directly control a numerically controlled cutting tool. The cavity dimensions are read with a non-contact sensing system.

Contamination Detector
NASA/MSFC/Thiokol Corp., Paul Karner, (801)863-3511
Contamination Scanning is a highly sensitive method used to qualitatively evaluate the cleanliness of surfaces. Conscan used Optically Stimulated Electron Emission (OSEE) technology to measure the emissions of electrons from metallic substrates.

Automated Assembly of Large Space Structures
NASA/LaRC, Ralph W. Wills, MS 152D, (804)864-3121
A research facility for automated assembly of large space structures has been established. It consists of a commercial robot arm mounted on a 2D translational motion base and a rotational motion base on which a truss is assembled has been constructed and is operational. The truss is composed of 102 members each 2m long.

Automated Robotic Truss Assembly Program (ARTAP)
NASA/LaRC, Cheryl L. Allen, Mail Stop 152D, (804)864-4438
The Automated Robotic Truss Assembly Program (ARTAP) is used to study methods of in-space assembly and construction of large truss structures using automated, robotic systems. A robot is tasked to pick up a truss member from a storage tray and install it within a structure.

Interactive Scene Analysis Module (ISAM)
NASA/LaRC, Virginia Hampton, Mail Stop 152D, (804)864-6674
ISAM provides the ability to quickly and accurately initialize and verify the database representing a telerobotic task environment using a 3-D graphic overlay modelling, video imaging and laser radar based range imaging. verifiable task space model is generated providing location and orientation data for objects in a task space.

Machine Vision System for Automated Structural Assembly
NASA/LaRC, Virginia Hampton, Mail Stop 152D, (804)864-6674
The system is designed to provide sensor based guidance for fully automated and operator assisted assembly of tetrahedral truss structures. The system determines the error between the "taught" position of the targeted truss joint receptacle and the actual position of the robot's end effector.

Rule-Based Script Generator for Command of Telerobotic Systems
NASA/LaRC, Virginia Hampton, Mail Stop 152D, (804)864-6674
The Expert Script Generator (ESG) allows operators of telerobotic systems to plan and define truss assembly operations using a high level task intuitive language. It simplifies operator interaction with the telerobotic system by basic to the construction of trusses.

Laboratory Telerobotic Manipulator
NASA/LaRC, Walter Hankins, Mail Stop 152D, (804)864-6696
The Laboratory telerobotic Manipulator (LTM) is a versatile, software/hardware reconfigurable telerobotic system designed and built for the purpose of studying space telerobotics. The LTM is a full, dual-armed, force-reflecting variety of other devices to control the slave arms or even the master arms functioning as slaves.

Advanced Planning System
NASA/JSC, Dennis Lawler, ER2, (713)483-2037
This project addresses the development and utilization of an advanced scheduling system developed in ADA and X- Windows on Unix Platform for a variety of applications: project scheduling assembly planning, etc.

Fuzzy Control Systems
NASA/JSC, Dennis Lawler, ER2, (713)483-2037
The utilization of Fuzzy Control has been shown to be more robust than conventional control technologies for non linear control problems. These projects explore the utilization of Fuzzy Control Systems for diagnostics of control of Space Station reboost engine blowdown modes, and control of toxic ammonia flow in the Space Station's thermal control system.

Autonomous Robotics
NASA/JSC/MDAC, Don Woods, (713)280-1308
This project addresses the evolution of space robotic systems from teleoperated to completely autonomous, and addresses machine vision, world models, shared control, and other robotics technologies as needed.

Advanced Process Control Technology
NASA/MSFC, C. S. Jones, EH42, (205)544-2701
This program objective is to develop robotic weld process control hardware and software that can provide feedback on the integrity and quality of the weld. The weld sensing system developed must be able to accurately follow "expert system" process control algorithms and provide process adjustments.

Variable Geometry Truss
NASA/LaRC, Garnett Horner,
A variable geometry truss (VGT) has been designed, built and tested. The VGT has been used to control the vibrations of a beam.

Structural Vibration Suppression Using Active Struts
NASA/LaRC, Keith Belvin,
A truss has been augmented with several active struts. These active struts have piezoelectric ceramics attached to aluminum tubes.

Active Flutter Suppression Using Piezoelectrics
NASA/LaRC, Tom Noll,
Have demonstrated flutter suppression using piezoelectric ceramics on a small laboratory model and correlated experimental results with analytical predictions.

Marking Parts to Aid Robot Vision
NASA/LaRC, L. Barker, 152D, (804)864-6694
Early report on the premarking of parts for subsequent fast identification by a robot vision system. In general computer vision systems identify parts by analyzing their shapes, but this is a time-consuming process that hampers real-time operation.

Kinematic Equations for Resolved-Rate Control
NASA/LaRC, Keith Barker, 152D, (205)864-6694
Early tutorial on the development of resolved rate equations for real-time control of an industrial robot arm in teleoperation mode. The operator essentially "flies" the robot hand by sitting at a remote console with a three-axis, aircraft-type controller in each hand.

Puma Robot Hand Singularity Avoidance
NASA/LaRC, Keith Barker, 152D, (804)864-6694
A teleoperator can now accomplish pitch maneuvers of a robot hand that were not previously possible with a widely-used wrist mechanism (PUMA). Previously pitching even a slightly-rolled robot hand through the wrist singularily resulted in hitting wrist joint limits.

Coordination of Multiple Robot Arms With Resolved Rate Control
NASA/LaRC, Keith Barker/Don Soloway, 152D, (804)864-6694
This appears to be the first time ever that dual industrial robot arms were automatically coordinated in teleoperation with resolved rate control, and the work received considerable attention. Kinematic resolved rate control arms in the movement of a commonly-held object.

Overcoming Robot-Arm Elbow Joint Singularity
NASA/LaRC, Keith Barker/152D, (804)864-6694
Full extension of a robot arm corresponds to a singular configuration, and the usual resolved-rate control equations, "blow up". To overcome this, an auxiliary set of equations were developed to allow the arm to be fully extended.

Computing Relative Joint Positions of Robot Arms
NASA/LaRC, Keith Barker/152D, (804)864-6694
A vector-algebra method has been developed for extracting the Denavit- Hartenberg parameters, which precisely define transformation matrices from one joint axis system for any assembled robot arm. The robot arm is positioned by specified zero position; and then the location of a point on the robot hand is measured with respect to a fixed world axis system.

Paladin Tactical Decision Analysis System
NASA/LaRC, Aircraft Guidance and Control Branch
Paladin is a knowledge-based system designed to perform situation assessment in an air combat simulation system. Paladin uses sensor information and aircraft status information to determine a mode of operation for the aircraft.

Intelligent Robot Sensor and Control Processing
NASA/JPL, G. Rodriguez, (818)354-4057
Develop methods and computer programs for robot mathematical modeling and sensor and control processing. Project includes fundamental research in modeling the behavior of robots together with computer simulation and physical laboratory experimentation.

Optimized Resolved Rate Control of Seven DOF Telerobotic Manipulator (LTM)
NASA/LaRC, L. Keith Barker, Mail Stop 152D, (804) 864-6694
Shaded graphics model of 7 DOF manipulator was driven in real time by optimized resolved rate equations with teleoperator inputs from six-axis hand controller or keyboard. The solution is a trade-off between small rates and the joint angles.

Real Time Neural Network Based Nonlinear Controller
NASA/LaRC,Donald I. Soloway, M.S. 152D, (804)864-6518
The first step in the realization of a practical real-time neural network based nonlinear controller for multiple joint manipulators has been accopmlished- . A Volterra series approach has been applied to the identification on nonlinear systems which are described by a neural network model.

Telerobotic Autonomous Control for Time Delayed/Ground-Remote Operations
Jet Propulsion Laboratory, W. F. Zimmerman, MS 198-219, (818)354-0234
The shared control/operator interface capability developed under this task augments teleoperation by allowing certain elements of a task to be controlled autonomously while the operator controls the more coarse control and has been evaluated by the technical community, and considered essential to the control of the intended robotic systems on-board the SSF.

Generic Telerobot Primitives
NASA/JPL, J. H. Smith, MS 601/237, (818)354-1236
Developed generic telerobot primitives and their definitions for detailed analysis of telerobot activities. A telerobot "command language" was also developed that uses the generic telerobot primitives to characterize telerobot operations.

COSMOS (Common Spaceborne Multiprocessor Operating System)
NASA/JPL, Dr. Blair Lewis, MS 198-231, (818)354-0912
The objective is to develop a real time, general purpose computing system and environment which addresses the high reliability needs of interplanetary spacecraft and planetary rovers. Max is a fault tolerant parallel computing architecture specifically adapted to tight resource limitations.

Unmanned Ground Vehicle Mobility
NASA/JPL, D. Bickler, MS 158-224, (818)354-5488
The mobility of conventional 4 wheel - 4 wheel driven wheeled vehicles has been dramatically improved, for low speed unmanned ground vehicles, with a new generation of both ultra-high mobility wheeled and legged vehicles.

Unmanned Ground Vehicle Navigation and Control
NASA/JPL, Brian Wilcox, MS 107/104, (818)354-4625
Between the extremes of teleoperation (i.e. no autonomy) and full autonomy, various degrees of supervised unmanned ground vehicle navigation and control modes are possible.

Stereo Television for Teleoperation
NASA/JPL, Dr. Daniel Diner, MS 198-219, (818)354-9134
The goals of this work are to derive the mathematics of 3-D television with a human observer (for low and high-precision teleoperation and supervised automation), to learn if true-to-scale 3-D TV is possible, and to verify the derivation and analysis of 3-D TV.

Emergency Response Robotics
NASA/JPL, Dr. Henry Stone, MS 198-219, (818)354-9051
The goal is to develop a mobile robot to be used by emergency response teams to perform incident localization, hazardous material identification/classification, site surveillance and monitoring, and ultimately incident base for climbing stairs and negotiating moderately-sized obstacles.

Assembly Sequence Planning System for Large Truss Structures
NASA/JPL, L.S. Home-de-Mello, MS 525-3660, (818)306-6158
An artificial-intelligence based system assists mechanical engineers in creating correct and efficient assembly sequences for large truss structures. The system uses a hierarchical approach, planning at the level of tetrahedral and pentahedral subunits rather than at the level of stress.

CASA Gigabit Network Test-Bed
NASA/JPL, Dr. Larry Bergman, MS 300-329, (818)354-4689
The key goal to the CASA test-bed research project is to characterize the role that high-speed wide-area networks can play in providing better resources for solving large-scale scientific and applications. The CASA test-bed is computational resources for leading-edge scientific problems, regardless of the geographical location of these resources.

Sample Acquisition, Analysis and Preservation
NASA/JPL, Dr. Kim Aaron, MS 125-214, (818)354-2816
The Sample Acquisition, Analysis and Preservation (SAAP) Project develops critical technologies for the identification, acquisition, analysis and preservation of materials for in-situ science and Earth return. The focus automated sample acquisition.

Dexterous, High Power and Precision Manipulation
NASA/JPL, Dr. A. K. Bejczy, MS 198-219, (818)354-4568
The 8-DOF manipulators, with redundant (4-DOF) wrist and (4-DOF) arm structure incorporates a variety of features not found in other laboratory or industrial manipulators. It has a fully revolute configuration with no lateral offset at joint axes, a high 1 to 4.

Solar Max Satellite Repair (SMSR) Experiments
NASA/JPL, Dr. A. K. Bejczy, MS 198-219, (818)354-4568
This is the practical demonstration and evaluation of the sensing and computer-aided end-to-end Advanced Teleoperation (ATOP) system capabilities. The simulated SMSR was selected since it is very rich in teleoperation EVA astronauts in the Space Shuttle Bay in 1984.

Preview and Force-Reflecting Graphics Displays
NASA/JPL, Dr. A. K. Bejczy, MS 198-219, (818)354-4568
The goals are creating high fidelity graphics representing two new 8-DOF AAI robot arms such that the robot are graphics can directly be driven by the advanced teleoperator computer control system, creating a "sense" of contact image of an object. The contact force or torque is translated to the operator as a force feedback and displayed visually on the graphics monitor.

Synthesis of Model-Based/Neural Network Control for Robot-Environment
NASA/JPL, Dr. S.T. Venkataraman, MS 198-219, (818)354-9290
This work conducts basic research to synthesize a new generation of robot control systems that combine recent advances in model-based robot control and neural-network adaptive control algorithms. It aims to achieve a previously unattainable level of robust interaction with unstructured environments.

Strip Winding System for ASRM Processing
NASA/MSFC/Aerojet, Dwayne Robertson, (601)423-0684
Strip winding robot system applies rubber strips to the inside of shuttle rocket motor cases. Feedback of the application pressure maintains constant pressure on extruded rubber tape.

Contamination Scanning Robot System
NASA/MSFC/Aerojet, Dwayne Robertson, (601)423-0684
Two robots are utilized for refurbishment of Advanced Solid Rocket Motor Cases and nozzle components by scanning the surface for contamination using Optically Stimulated Electron Emission (OSEE) a "smart" end effector senses and controls standoff and orientation.

Painting Robots for ASRM Processing
NASA/MSFC/Aerojet, Dwayne Robertson, (601)423-0684
Two robots are utilized for refurbishment of Advanced Solid Rocket Motor Cases and nozzle components. Robot controller monitors paint viscosity, pressure, volumetric flow, standoff, and travel rate.

High Pressure Waterblast Robots for ASRM Refurbishment
NASA/MSFC/Aerojet, Dwayne Robertson, (601)423-0684
Two robots are utilized for refurbishment of Advanced Solid Rocket Motor Cases and Nozzle Components utilizing 10.5 Ksi pressure water. Process parameters under feedback control include water pressure, flow rate, standoff distance and travel speed.

Media Blast Robot Cell for ASRM Refurbishment
NASA/MSFC/Aerojet, Dwayne Robertson, (601)423-0684
Two robots are utilized for refurbishment of Advanced Solid Rocket Cases and Nozzles. Plastic media is used to remove insulation from components. The robots utilize off-line programming of path and process parameters.

CATEGORY: SENSORS

Large Field-of-View CCD Camera With Fast Read-Out Design
NASA/MSFC, Hagyard, ES52, 205 544-7612
Under a SBIR grant to a local company, a unique CCD camera and data-handling system was developed as a concept-verification breadboard for a future space- based solar vector magnetograph. The camera provides a total array of 2048 x storage.

High Temperature Superconducting Thin Film Research
NASA/MSFC, Sisk, ES63, (205)544-7734
High temperature superconducting materials are difficult to fabricate into bulk conductors, such as wires. High quality, stable thin film deposition techniques provide a means of producing superconducting circuits in various configurations.

Helium Cryogenic Coolers
NASA/MSFC, Urban, ES63, (205)544-7721
To adapt and improve a helium continuous flow refrigerator to cool a typical infrared astronomical instrument. This cryo cooler allows infrared sensors to operate at cooler temperatures than is possible with pumped, boiled, or superfluid helium.

Non-Linear Optical Materials
NASA/MSFC, Vlasse, ES74, (205)544-7781
Study of NLO materials and in particular L-arginine phosphate (LAP) using solution growth techniques in view of fabricating large LAP crystals of excellent optical quality. The second harmonic generation (SHG) properties perfection.

High Temperature Superconducting Materials
NASA/MSFC, Vlasse, ES74, (205)544-7781
Preparation and characterization of bulk high-temperature superconductors. This study involves the optimization of processing methods to produce bulk material with high current carrying capacity and improved flux trapping.

Water Window Imaging X-Ray Microscope
NASA/MSFC, Hoover, ES52, (205)544-7617
Develop high resolution X-ray microscope for producing high contrast images of carbon based structures in living cells. Protein Crystal Research and Pharmaceuticals.

Coherent LIDAR Imaging
NASA/MSFC, James W. Bilbro, EB23, (205)544-3467
This project looks at the use of employing coherent LIDAR techniques to create Doppler velocity coded images. This system can provide information regarding a remote target relative to its velocity, angular position, range, altitude, and rotation rate.

Real-Time Network Analysis
NASA/MSFC, Gray Settle, EB32, (205)544-5548
Study and analysis of the Ethernet network in the Huntsville Operations and Support Center(HOSC) was performed by Mississippi State University. This network is used for real-time distribution of data for monitoring of space launches and missions.

A Vision-Based Weld Quality Assurance System
NASA/MSFC, William Boglio, EB44, (205)544-3806
The goal of the investigation is to develop an intelligent system which uses visual information to detect and analyze defects in materials and structures. The approach taken is to use readily available computing hardware, and to detection analysis processes.

Neural Networks for Image Processing System
NASA/MSFC, Linda Brewster, EB44, (205)544-0169
To develop and demonstrate the uses of Neural Network Theory in image processing. The objective to reduce the amount of data processing that is expected to be received from the mission to Planet Earth program.

Video Sensor That Provides Range, Range Rate and Attitude Information
NASA/MSFC, Mike Brooks, EB24, (205)544-3699
Develop a video sensor that can provide range, range rate, and attitude information to a spacecraft flight control system. The sensor will allow development of automatic rendezvous and docking with a target spacecraft.

Automated Fluid Interface System (AFIS)
NASA/MSFC, Tom Bryan, EB24, (205)544-3550
Develop an automated system for bringing together electrical and fuel lines between a satellite and on-orbit servicing spacecraft. Servicer must first dock with satellite, then AFIS checks satellite for preparedness to take on fuel, connects electrical and fuel lines and performs over transfer.

Solid Rocket Motor Roundness Measurement
NASA/MSFC, Ralph Kissel, EB24, (205)544-3510
Provide diameter measurement on the 12-foot SRB motor cases to an accuracy of ± 0.004 inches. This allows circumferences to be selected to provide a desired interference fit for proper segment sealing.

Real-Time Radiography (RTR) Inspection of Solid Rocket Motors
NASA/MSFC, Ted Kublin ER41, (205)544-8631
This project obtained performance parameters on a wide range of Real-Time Radiography equipment of different energy levels. Determined resolution as a function of the spatial location of defects.

Miniaturized Shear and Normal Stress Gauges
NASA/MSFC, Ted Kublin ER41, (205)544-8631
Shear and Normal stress gauges were developed to embed in a solid rocket motor to monitor internal stresses without affecting the structural integrity of the motor.

X-Ray Fluorescence Thickness Gauging (XRF)
NASA/MSFC, Ted Kublin ER41, (205)544-2681
X-Ray Fluorescence was developed to measure the thicknesses of layers applied to a solid rocket motor case and/or insulation. XRF detects/counts target trace elements and can be calibrated to determine layer thickness.

Dielectric Cure Monitoring of Elastomers with Feedback Controls
NASA/MSFC, Ted Kublin ER41, (205)544-8631
Use of a dielectric cure monitoring system to determine "degree of cure" of composite materials to optimize bonding of the next layer of material. Feedback controls can end the cure cycle when an appropriate signal is reached.

X-Pert Witness Panel Development
NASA/MSFC, Ted Kublin, (205) 544-8631
Developed a special-purpose witness panel that would undergo equivalent processing to the manufactured article and serve to monitor and control the actual processing environment seen by the article. Factors monitored included cleanliness and cure state.

Magnetic Resonance Imaging (MRI) of Large Solid Rocket Motors (SRM)
NASA/MSFC, Ted Kublin ER41, (205)544-8631
Preliminary evaluation of the use of Magnetic Resonance Imaging (MRI) activated by single-sided sensors, which are useful on large structures. This method could determine the cure state and thickness and coverage for insulation, liner, propellant, and composite cases.

Embedded Fiberoptic elements
NASA/MSFC, Ted Kublin ER41, (205)544-8631
Fiber optics elements embedded in polymetric materials in solid rocket motors are used to monitor progress of cure by detecting changes in spectrographic scans at ultraviolet and infrared wavelengths. Such elements continue to be during aging such as migration of species into adjacent layer; such as liner to propellant.

Weld Seam Tracking System for Tight-Fitting Aluminum Weld Joints
NASA/MSFC, Kirby Lawless EH42, (205)544-2821
A weld seam tracking system has been developed for tracking of joints that fit very tightly and have little or no discernible seam feature. The system will operate in spite of the high reflectivity of freshly machined aluminum surfaces that are scanned.

Weld Bead Profile Measurement and Control System
NASA/MSFC, Kirby Lawless EH42, (205)544-2821
A sensor system has been developed to measure the critical geometries of a solidified weld bead, and provide feedback to maintain process control. The system utilizes structured laser light and a CCD camera controlled by a mismatch and intersection angle of the parts to be joined.

Co-Axial Weld Vision System for Seam Tracking and Monitoring
NASA/MSFC, C. Jones, (205)544-2701
A CCD camera system mounted inside a Gas Tungsten Arc welding torch has been developed to provide seam tracking and weld process monitoring for robotic welding of the Space Shuttle Main Engine. The camera's optics are placed weld pool and seam.

Contamination Scanning Process
NASA/MSFC, Paul Gill / EH44, (205)544-2557
A prototype end-effector was developed to demonstrate the feasibility of automated non-destructive surface contamination detection system. Optically Stimulated Electron Emission (OSEE) technology was combined with a gantry robot to inspect full-scale solid rocket motor cases.

Embedded Fiber Optic Sensors for Composite Structures
NASA/MSFC, C. Wilkerson, (205) 544-8834
Investigate and develop techniques of strain measurement using the light transmission characteristics of optical fiber that would be applicable for use in an automated manufacturing process.

NASA Electric Portapull
NASA/MSFC, C. Wilkerson, (205) 544-8834
Develop and test a portable, electrically controlled tensile strength test system which reads actual load values from the sample. This system is for use on spray on thermal protective systems (TPS) such as MSA-2.

Weld Penetration Sensing and Control
NASA/MSFC, Jeff Ding / EE24, (205)544-2700
A weld penetration control system has been developed using optical detection of weld pool oscillations induced by pulsing the weld current in Gas Tungsten arc welds. The oscillations are processed to determine back-bead width. The with square-butt and u-groove joint preparations.

Comparative Test Results of Commercial Weld Seam Tracking Systems
NASA/MSFC, Jeff Ding/EE24, (205)544-2700
Three different weld-vision seam tracking systems were evaluated for use in robotic welding of the Space Shuttle Main Engine (SSME). The systems were subjected to a series of tests which simulated weld joint tracking in SSME applications.

Propellant Level Detection During Casting
NASA/MSFC, Ben Powers, EE51, (205)544-5580
Propellant casting height is accurately measured during the casting operation using a low average laser system. Propellant final cast height can be held to sufficiently close tolerances simplifying finishing operations.

Cutting Tool Optimization
NASA/MSFC, Ben Powers, EE51, (205)544-5580
Develop machining handbook containing parameters for machining composites using a polycrystalline diamond cutting tool. Statistically evaluated cutting tool parameters of insert nose radius and rake angle along with combination of variables in terms of cutting tool loads and temperature.

RSRM Propellant Chemical Analysis
NASA/MSFC, Ben Powers, EE51, (205)544-5580
Fourier Transform Infrared (FTIR) Spectroscopy and automated X-Ray fluorescence will be used for determining the key chemical composition and total solids in each propellant mix for the RSRM.

Sensory Overlays for Telepresence
NASA/ARC, Butler Hine, FII, MS244-4, (415)604-4379
Operational and prototype platforms have been built and operated in which the pilot of the vehicle uses navigational displays and images from on-board cameras displayed on T.V. monitors. These camera displays are sufficient for navigation, tracking, and some operational purposes.

Bond Surface Cleanliness Inspection Using Optical Stimulated Electron Emission
NASA/MSFC, H. D. Burns, EH12, (205)544-2529
Optically stimulated electron emission (OSEE) is utilized for cleanliness inspection of bonding substrates prior to bonding. The OSEE technique is the process in which UV photons interact with the surface to produce electrons.

Automated Non-Contact Foam Insulation Thickness Measuring System
NASA/MSFC/MMMSS/MAF, Francis J. Gutierrez, Advanced Quality Technology, (504)275-1859
Provide automated non-contact thickness measurements on foam insulation applied to NSTS External Tank. A hybrid electromagnetic/opto-electronic sensor enables coating thickness measurements to be made without contacting the insulation.

Computer Aided X-Ray Film Interpretation
NASA/MSFC/MMMSS/MAF, Ron Reightler/Mail Stop 3773, (504)257-1832 This system is being developed to aid in the interpretation of radiographic film for the Space Shuttle External Tank. This system utilizes a radiographic film digitizer to convert the X-ray data to a digital format.

Development of Advanced Measurement System for Large Objects
NASA/MSFC/MMMSS/MAF, John F. Malm/AQT Lab (3773), (504)257-1826
Single beam tracking laser interferometer developed at the National Institute of Standards and Technology (NIST) is the major component of the measurement system. The design is based on a spherical three dimensional measurement concept that is ideally suited for complex geometries and curved surface.

Smart Hydrogen Sensor
NASA/SSC/STL, Chuck Thurmon, (601)688-1023
The output of a conventional hydrogen detector is fed to a microprocessor. The microprocessor computes the rise time of the detector output to predict the concentration of gaseous hydrogen present at the detector.

Optical Multi-channel Analyzer
NASA/SSC/STL, Don Chenevert, HA20, (601)688-3126
The OMA is an instrument for performing high spectral resolution spectroscopy on the SSME engine plume during testing at SSC. The output of the OMA is correlated to known emission spectra of materials expected to be found in the plume.

Shuttle Ice Detection System
NASA/SSC/STL, Bruce Spierling, HA20, (601)688-3588
Develop a multi-spectral imaging system which could detect and quantify the presence of water, ice and frost formations on the Space Shuttle External Tank (ET) on the launch pad during the launch cycle. The system included an imaging camera as well as a processing system.

Advanced Force Torque Control
NASA/JSC, L. Stokes, ER4, (713)483-8965
External control input of force and moments information to actively comply with environment. It has the capability to conform to external stimuli to keep handle part or payload from jamming and reduce reacting loads.

Image-Based Tracking
NASA/JSC, R. Juday, EE6, (713)483-1486
Sensor technologies and processing techniques are being developed for recognizing and determining the position and pose of objects. NASA applications are spacecraft rendezvous, docking, and planetary landing and robotics.

Fuzzy Logic Controller For Simplified Aid For EVA Rescue (SAFER)
NASA/JSC, Hal Hiers, ER2, (713)483-2036
The SAFER is a self rescue device proposed for use by each EVA crew member on the Space Station and Shuttle in the event the crew member is separated from the vehicle during EVA. The system is composed of structural, electrical, propulsion, hand controller, and microcontroller elements.

Capacitance Proximity Sensor
NASA/JSC, Lou McFadin, ER4, (713)483-8539
Capacitance proximity sensor: This sensor coupled with a microprocessor can sense objects in the vicinity of 12". The sensor field is by nature wide view.

Modal Analysis Equipment
NASA/MSFC/Boeing, Frank Jackson,
Equipment to simulate structural deflection and finite analysis to refine design requirements. System is computer work station based and provides Design Engineering analysis of loading and deflection simulation in real time.

Real Time Radiography Inspection of Welding on Space Station Module Structures
NASA/MSFC/Boeing, M. Biggerstaff, (205)545-4986
Real-time radiography applied to the welding operations on the Space Station Freedom module cylinders. Allows quality verification of weld while production continues on an adjoining weld joint.

Computer Controlled Theodolite Tool Mastering
NASA/MSFC/Boeing, Glenn Blanton, (205) 461-5316
Tool and part inspection utilizing computer controlled theodolite to master and check large structures.

Mass Flow Meter Leak Check
NASA/MSFC/Thiokol, Dale Hibbert, (801)863-3511
A mass flow meter system (MFM) is being developed to perform the leak test on the Space Shuttle Redesigned Solid Rocket Motor, joint seals that are leak tested prior to flight to ensure integrity of the seals. The MFM system has required for the pressure decay system.

Ultrasonic Bond-line Inspection
NASA/MSFC/Thiokol Corp., Paul Karner, (801)863-3511
The Ultrasonic RSRM Bond-line Inspection System (URBIS) consists of four customized scanners and a generic scan controller, four channel data acquisition system, fully programmable ultrasonic front end, data storage and or through-transmission inspection.

Ultrasonic Bolt Preload
NASA/MSFC/Thiokol Corp., Paul Karner, (801)863-3511
The Ultrasonic Bolt Preload Measurement System used at Thiokol is capable of evaluating residual bolt preload during the torquing operation with high accuracy. The system consists of an ultrasonic pulser/receiver, a computer, and a socket-mounted transducer.

Automated Ultrasonic Thickness Measurement System
NASA/MSFC/Thiokol Corp., Paul Karner, (801)863-3511
The AUTO Gage is a computer controlled ultrasonic measurement instrument that is used to measure the wall thickness of metallic components during each refurbishment cycle of Redesigned Solid Rocket Motor. It automatically determines the optimum signal strength for measurement and compensates for a variety of system variations.

Eddy Current Inspection
NASA/MSFC/Thiokol Corp., Paul Karner, (801)863-3511
Eddy Current is used to detect fatigue cracks in various threaded and through holes on Space Shuttle Redesigned Solid Rocket Motor case segments. Inspections are presently performed manually using the Uniwest Eagle Plus qualified.

Electro-Optical Pan/Tilt/Zoom: A miniature Viewing System
NASA/LaRC, Walter W. Hankins, Flight Systems Directorate, (804)864-6696
This project is creating the capability to produce electronic Pan/Tilt of a TV image to and from within a hemisphere forward of a TV camera. A fisheye lens image is imposed on a very high density CCD array.

Fiber Coupled Coherent Laser Radar Measurement System
NASA/LaRC, Virginia Hampton, Mail Stop 152D, (804)864-6684
The Fiber Coupled Coherent Laser Radar Measurement System performs the optical measurement of range (proximity), tactile pressure (touch), and force with a single miniature sensor head and supporting electronics. The system robotic arms, end effectors, and tools.

FM/CW Coherent Laser Radar 3-D Vision System
NASA/LaRC, Virginia Hampton, Mail Stop 152D, (804)864-6684
The FM/CW Coherent Laser Radar 3-D Vision System is a monostatic radar that homodynes the FM signal reflected from a target with an internal reference signal to generate a beat frequency that is directly proportional to the at a rate of four 256 x 256 pixel range images per second.

Autonomous Landing (for Planetary Exploration)
NASA/JSC, Ken Baker, (713)483-2041
The objective of this project is to develop technology to enable a planetary exploration spacecraft to land safely in the face of surface hazards, accurately and autonomously. Current work is focused on the definition of image matching approach to terminal navigation and exploratory simulation of on-board detection of surface hazards.

Brush-less Torquemeter
NASA/MSFC, H. P. Stinson, EP62, (205)544-7077
This program developed a Brush-less Torquemeter capable of measuring the SSME low pressure fuel turbopump torque during engine operation and was completed December 1990.

Assembly & Test Leak Detection
NASA/MSFC, W. T. Powers, EB22, (205)544-3452
The objective of this program is to develop a video imaging, gaseous leak detection system for use in assembly and test or preflight operations of Earth-to-Orbit liquid propulsion rocket engines. The video imaging system leak locations for the video system involves use of an expanded laser illuminator to identify the leak sources.

Bearing Deflectometer
NASA/MSFC, M. E. Koebel, EB33, (205)544-3660
The objective of this program is to develop, design, fabricate and install a fiberoptic deflection detector in the SSME High Pressure Oxygen Turbopump to monitor deformations for the bearing's outer race. This measurement would provide indications of bearing wear and life.

Non-Intrusive Hot Gas Temperature Measurement
NASA/MSFC, W. T. Powers, EB22, (205)544-3452
The projects objective is to develop a non-intrusive temperature measurement instrument capable of measuring hot gas temperatures in the Earth-to-Orbit liquid propulsion rocket engines. The device being developed is an infrared/ radiometer based sensor.

Non-Intrusive Speed Sensor For Turbopumps
NASA/MSFC, W. T. Powers, EB22, (205)544-3452
The purpose of this program is to develop a non-intrusive speed sensor capable of safe operation in the cryogenic LOX/H2 atmosphere of rocket engine turbopumps. The validation of this turbopump shaft speed sensor is scheduled NASA's Technology Test Bed Engine.

Nozzle Exit Plane Measurement System
NASA/MSFC, W. T. Powers, EB22, (205)544-3452
The objective of this program is to develop and validate a measurement system capable of mapping the temperature, spectral concentration, and velocities in the exhaust plume of a rocket engine at the exit plane of the nozzle. Testing will be conducted on the Marshall Space flight center Technology Test Bed in 1993.

Optical Plume Anomaly Detector
NASA/MSFC, W. T. Powers, EB22, (205)544-3452
The objective of this project is to develop a spectroscopic instrument that provides real time detection of anomalies species in the exhaust plume of a rocket engine such as SSME. This instrument coupled with appropriate catastrophic engine failures and/or provide indication preventive maintenance requirements.

NDE of Rocket Motor Components
NASA/MSFC, Ron D. Beshears, EH13, (205)544-2550
The objective of this program is to design, build, and demonstrate a prototype, compound lens, endoscopic inspection tool for viewing internal cavities or rocket motors. This tool will provide a cylindrical view of computer.

Circularity and Inner Diameter Station (CIDS)
NASA/MSFC, Jack Phillips, (205)544-2199
The CIDS measures circularity and the inner diameter of the AXAF mirrors through the use of contact air bearing probes. Data acquisition is from the station PC.

Mechanical Profilometer Station (MPROS)
NASA/MSFC, Jack Phillips, EJ31, (205)544-2199
The MPROS measures axial figure on the inside optical surface of the AXAF mirrors. The MPROS employs an axial scanning contact probe in combination with a reference bar as a flatness standard.

Micro Phase Measuring Interferometer (MPMI)
NASA/MSFC, Jack Phillips, EJ31, (205)544-2199
The MPMI is used to measure the high spatial frequency figure of the AXAF mirrors. The MPMI uses a Wyko instrument mounted to a linear slide assembly. The Wyko instrument and mirror are positioned by the station PC.

Advanced Non-Intrusive Flowmeter
NASA/MSFC, W. T. Powers, EB22, (205)544-3452
The objective of this research program is to develop a non-intrusive flow measurement device to accurately measure cryogenic fluid flows in liquid propulsion systems. The selected candidate to provide reliable, accurate measurements of liquid oxygen flows is an ultrasonic flowmeter.

Windshear Safety Advisor
NASA/LaRC/Princeton University, Robert Stengel
A rule-based expert system for windshear avoidance was developed based on knowledge derived from the windshear training aid developed by the FAA. The expert system implements windshear avoidance criteria stated and implied in the windshear training aid.

Intensity Dependent Spread (IDS) Processor
NASA/LaRC, Friedrich O. Huck/473, (804)864-1517
The Intensity Dependent Spread (IDS) Processor enables the acquisition of discernible video images under conditions of an extreme illumination variation within a single frame or field of view. The IDS Processor is not commercially available from Odetics, Inc.

Laser Multiport Proximity and Shape Sensor
NASA/LaRC, Pleasent W. Wood/152D, (804)864-6685
The Laser Multiport Proximity and Shape Sensor (LAMPSS) is an in-house prototype development project. LAMPSS is all fiber FM/CW Coherent Laser Radar (CLR) multiplexed among 25 fibers and associated lenses terminated on a planar surface in the form of a rectangle.

Fault Diagnosis of Antenna Pointing Systems
NASA/JPL, P. Smyth, MS 238-420, (818)354-3768
The goal is to develop an on-line unattended computer controlled monitoring system which can detect and identify problems in the pointing systems of NASA's large 70m and 34m ground-based DSN (Deep Space Network) antennas. The current, tachometer, wind measurements, etc.

Silicon-Based Infrared Sensors-(HIP) Infrared Detectors
NASA/JPL, Dr. True-Lon, MS 302-231, (818)354-7368
The objective is to develop Si-compatible IR sensors for 3-20 4m focal plane array applications utilizing Si MBE in support of NASA's future sensor needs. New materials growth technologies using Si MBE have been developed including impurity, low temperature substrate preparation technology, columnar silicide.

Microsensors
NASA/JPL, Dr. Carl Kukkonen, MS 180-604, (818)354-4814
A unique class of microsensors using electron tunneling position detection has been developed. Electron tunneling between metallic electrodes (separated by a vacuum gap) provides extreme sensitivity to position change of the electrodes.

Advanced Image Processor (AIP)
NASA/JPL, Dr. Jerry E. Solomon, MS 168-522, (818)354-2722
The objective is to develop and demonstrate efficient algorithms for real-time extraction of geophysical/biophysical parameters from imaging spectrometer and other high-rate imaging instrument data streams; and to processing architectures for implementation of these algorithms.

Communications System for Power System Distribution Automation
NASA/JPL, Dr. H. Kirkham, MS 303-300, (818)354-9699
A hardware/software communications system (AbNET) has been designed for distribution applications. It can also find application in substation monitoring and control.

Autonomous Analysis
NASA/JPL, Dr. Susan Eberlein, MS 168-522, (818_354-6467
This task develops and implements autonomous, real-time methods of high dimensional image data reduction, information extraction, and goal-driven decision making. Datasets are collected from broad-band cameras and imaging character of a scene as well as mineral composition.

Optical Protocols for Advanced Spacecraft Networks
NASA/JPL, Dr. Larry Bergman, MS 300-329, (818)354-4689
This task develops a novel local area network (LAN) technology and associated protocols that exploit the THz bandwidth of single-mode optical fibers by implementing networking prototcols entirely in the optical domain. Using multiple-access and non-blocking crossbar functionality is achieved with inherent data security for a host at a very high data rate.

Remote Surface Inspection
NASA/JPL, Dr. Samad Hayati, MS 198-219, (818)354-8273
A general inspection technology is being developed for health monitoring of space structures and space platforms including the Space Station Freedom. Research will be performed in operator assisted and automated remote inspection.

CATEGORY: CONTROLS

Flexible Body Control Using Neural Networks
NASA/MSFC, Bukley, ED12, (205)544-0054
The goal of this project is to evaluate neural networks as a tool for control of flexible structures. This will be done by applying several different neural net control strategies to the Control Structures Interaction Suitcase Demonstrator (a flexible beam with uncontrollable & unobservable modes).

Control of a Flexible Beam Using Fuzzy Logic
NASA/MSFC, Bukley, ED12, (205)544-0054
The goal of this project is to investigate and demonstrate the applicability of fuzzy control techniques to flexible structures. This is to be done by simulating control of the Control Structures Interaction Suitcase Demonstrator (a flexible beam with uncontrollable and unobservable modes).

Integrated Nondestructive Evaluation Data Reduction System (INDERS)
NASA/MSFC, Stucker, ER41, (205)544-0189
The INDERS system was initiated in 1984 as an IR&D effort in response to Inertia Upper Stage(IUS) nozzle failures(Palapa & Westar). The system is operational and establishes a standard set of tools which can easily be applied to the dispositioning of solid rocket motor nozzle components using NDE data.

Manufacturing Automation for the ASRM and RSRM
NASA/MSFC, G. Settle, EB32, (205)544-5548
Plans for the Advanced Solid Rocket Motor plant in Yellow Creek, MS and the Redesigned Solid Rocket Motor plant in Utah include the automation, to the extent practical, of the manufacturing process. A primary objective is to provide a paperless environment, especially on the shop floor.

Engine Control and Health Monitor System (ECHMS)
NASA/MSFC, Russell Mattox, EB32, (205)544-3571
Perform studies and analysis to define an overall architecture of a liquid propulsion rocket engine digital computer controller. The architecture shall be redundant and will be capable of self-testing and redundancy management.

Environmental Control and Life Support System Advanced Automation Project
NASA/MSFC, Amy Cardno, EB42, (205)544-3039
The Environmental Control and Life Support System (ECLSS) Advanced automation project is developing intelligent systems to monitor and diagnose problems on the space station Freedom. It uses model-based diagnosis to provide the ability to detect and isolate failures.

Neural Networks in Life Support Instrumentation Analysis
NASA/MSFC, Amy Cardno, EB42, (205)544-3039
Research into the use of Neural Network algorithms in analysis and synthesis of applicable data in the space station Environmental Control and Life Support System (ECLSS). If proven successful, these algorithms will reduce of operator sensor synthesis.

Automatic Programming of Simulation Models
NASA/MSFC, Robert Crumbley, EB42, (205)544-2624
The purpose of this task was to define and develop an interactive graphical interface to the Autonomously Managed Power System (AMPS). Another objective is to use the automatic programming techniques to reduce the amount of detail that a programmer needs to know about the AMP system to develop software.

Cooperating Intelligent Systems
NASA/MSFC, Robert Crumbley, EB42, (205)544-2464
Provide conceptual and computational tools for attacking the knowledge problems created by multiagent systems. Develop domain specific automated decision making agent, treating the agents as part of a unified human-machine cognitive system.

Tolerance Allocation Decision Systems (TADS)
NASA/MSFC, Amelia Gillis, EB44, (205)544-4703
Software package which computes fabricatible optimized dimensional tolerances from CAD/CAM drawings and user's specifications. Optimized tolerances improve quality of fit, while minimizing cost.

A Natural Language Interface to Databases
NASA/MSFC, Robert Crumbley, EB42, (205)544-2464
Develop an interface to a database in order to determine the feasibility of natural-language interface. Desirability of the interface was addressed, and a better understanding of the capabilities of this type interface was investigated, including some limits.

Integrated Engineering Environment
NASA/MSFC, Steve Jones, EB44, (205)544-4373
The primary goal of this effort is to develop a paperless system engineering documentation production, processing, release and distribution through the use of existing computer-based interactive graphics workstation hardware and "paperwork" is expected to greatly increase efficiency and productivity of technical organizations.

ADA as an Implementation Language for Knowledge-Based System
NASA/MSFC, Robert Crumbley, EB42, (205)544-2464
Explore the commonality between ADA and LISP knowledge-based systems. This task identified which characteristics of an application are best approached with procedural languages and which ones are best approached with symbolic languages.

Intelligent Remote Power Controller (RPC)
NASA/MSFC, Norma Dugal-Whitehead, (205)544-3304
Add more fault detection and protection to the present RPC design including soft fault detection. The RPC developed in this task contains an internal microprocessor that can be used to program the RPC characteristics based on a variety of sensed parameters including fault currents, input voltages, etc.

Programmable Power Processor
NASA/MSFC, John Bush, EB12, (205)544-3305
Power regulator utilizes microprocessor generated signals to control output function. The internal microprocessor generates digital and analog control signals based on internal and external digital and analog signals.

Superconducting Magnetic Bearings
NASA/MSFC, Decher, ES61, (205)544-7751
To develop high temperature superconducting materials and to apply these materials into the development of active and passive magnetic bearings to levitate the shafts of rocket engine turbo-machinery. These bearings would increase the efficiency of the rotating components, and would also greatly reduce vibration dynamics problems.

Man/Computer Interactive Data Acquisition System (McIDAS)
NASA/MSFC, Arnold, ES43, (205)544-1646
A data acquisition system has been designed and used to allow meteorological data from satellites, aircraft instruments and other sources to be displayed and interactively formatted for use by researchers. System exhibits data in a variety of formats chosen by the researcher for most intelligent display.

Autonomously Managed Power System (AMPS)
NASA/MSFC, Norma Dugal-Whitehead, EB12, (205)544-3304
A high voltage power system breadboard (250Vdc) with algorithmic control of battery, solar array and load allocation. Sensing throughout the system provides for cell protection in the high voltage batteries, for load analysis, and automatic balancing, to assure that "noisy" loads are not placed on a bus with noise sensitive equipment.

Electrical Power System Fault Study
NASA/MSFC, Norma Dugal-Whitehead, EB12, (205)544-3304
A study of electrical power system faults was performed. This information is being used to place faults within AMPS (Autonomously Managed Power System), SSM/PMAD (Space Station Module/Power Management and Distribution) and the Large Autonomous Spacecraft Electrical Power System.

Space Station Power Management and Distribution Automated Sybsystem Project
NASA/MSFC, Louis Lollar, EB12, (205)544-3306
This project consists of an autonomously operating high fidelity hardware model of the SSF Module Power Subsystem. Using advanced computer technologies and state-of-the-art DC switchgear, an 18KW power subsystem is controlled autonomously.

Power Factor Controller (PFC)
NASA/MSFC, Frank Nola, EB24, (205)544-3508
The PFC is a by product of Solar Energy Research conducted at MSFC in the 70's. The PFC is a smart electronic controller that connects to the wires going to any induction motor, reducing heat and power consumption.

Universal Analog Data Multiplexing System
NASA/MSFC, James Currie, EB24, (205)544-3524
The Universal Analog Data Multiplexing System is physically an electronic circuit board that interfaces to a computer. This board has a number of analog channels that multiplexed at a high rate of speed.

NDE Manufacturing Workstation
NASA/MSFC, Mark Stucker ER41, (205)544-0189
An NDE workstation is under development as a manufacturing tool to be applied during fabrication of solid rocket motor nozzles and components. The workstation will allow the manufacturing engineer to store, retrieve and manipulate in-process manufacturing data versus part specifications.

Automated Nozzle-to-Case Bonding Development
NASA/MSFC, EH44/Paul Gill, (205)544-2557
An automated mixing and dispensing process is being developed to assure consistency and void-free application of sealant in the solid-rocket-motor (SRM) nozzle-to-case joint. A six-axis gantry robot in conjunction with an automtated mixing and dispensing system is used to develop methods to apply the sealant.

Pultrusion
NASA/MSFC, William McMahon/EB44, (205) 544-2802
Pultrusion is generally considered to be the simplest and most economical of automated composite manufacturing processes. The process essentially goes from the raw materials to the finished product all in one process.

Automated Fastner Lab
NASA/MSFC, David Hoppe, (205)544-8836
An Automated Fastener Lab will provide an efficient means of determining a fastener's loading characteristics. The Fastener Lab can verify a fastener's calculated preload values by comparing test data to calculated data.

Offline Programming of Welding Robotic Systems
NASA/MSFC, Jeff Ding EE24, (205)544-2700
An advanced robotic welding off-line programming system has been developed to support welding of Space Shuttle Main Engines (SSME). The purpose of the system is to provide a flexible and adaptive robotic system to without requiring extensive access to the robot prior to the weld.

Manufacturing Simulation of a Chemical Processing Precleaning Operation
NASA/MSFC, Jeff Ding/EE24, (205)544-2700
A computer model has been developed to simulate the manufacturing flow for a chemical process and plating area to support refurbishment of the area to meet the requirements of Proposition 65, reducing the use of chemicals known to damage the environment or be hazardous to personnel. A report of the results and the ipact on the design of the facility is available.

Discrete Event Simulation to Design Flexible Manufacturing System
NASA/MSFC, Jeff Ding/EE24, (205)544-2700
A discrete-event simulation by computer has been performed to design a flexible Machining System(FMS) for manufacture of parts for the Space Shuttle Main Engine. A model of the system under study was constructed using a simulation language named SLAM-II.

Automated RSRM Dome Gritblast
NASA/MSFC, Ben Powers, EE55, (205)544-5580
Improved gritblast facilities, to allow for automated gritblast to replace a manual process. Gritblast boom speed and table rotation are constantly monitored by process controllers during blast operations.

Exterior Chemlock Application
NASA/MSFC, Ben Powers, EE51, (205)544-5580
A high volume/low pressure paint system was evaluated to spray "chemlock" on the exterior of segmented rocket motor joints. The previous method was to hand apply the chemlock with foam brushes.

RSRM Propellant Mixer Control
NASA/MSFC, Ben Powers, EE51, (205)544-5580
Obsolete Programmable Logic Controllers (PLC) were replaced with Trixonex fault tolerant (TMR) PLCs which utilize fault tolerant communications. Two redundant man-machine interfaces were added to provide a flexible video display of the process and alarm status.

Robotic Vision Processing System
NASA/ARC, Butler Hine, F11, MS 244-4, (415)604-4379
A hybrid digital electronic/analog optical robotic vision processing system has been developed to test concepts and algorithms for autonomous construction, and maintenance of structures. In our tests of the system to (such as a particular tool among a set of tools) at input image updates of 1 Hz in a two-dimensional plane.

Real-Time Adaptive Control Processing
NASA/ARC, Max Reid, FII, MS 244-4, (415)604-43678
High-speed optical matrix processing techniques are being used to provide real-time processing of control algorithms to damp structural vibration. Optical processing algorithms will be developed and hardware designed to implement a prototype hybrid optical-digital processor.

Automated Fault Management Based on Graph Models
NASA/ARC, Ann Patterson-Hine, FII, MS 244-4, (415)604-4178
Integrated methods for monitoring, diagnosis, and fault handling for complex systems have been developed based on agency standard system reliability models. Graph models such as diagrams and fault trees are used to prototype automated systems for fault monitoring and diagnosis.

Parallel Processing Research
NASA/ARC, Jerry Yan, FII, MS 244-4, (415)604-4381
Research in parallel processing has been carried out to support computational aerosciences, resulting in performance predictions of teraFLOPS and multiprocessor architectures. Software tools have developed for performance tuning and debugging of multiprocessor systems. Static and dynamic resource management strategies for multiprocessors have been developed.

Intelligent Scientific Instruments
NASA/ARC, David Thompson, FIA, MS 244-17, (415)604-4759
Development of control and analysis software for a differential thermal analyzer/gas chromatograph capable of autonomous behavior in soil sample analysis.

Constraint-Based Scheduling
NASA/ARC, Monte Zweben, FIA, MS 244-17, (415)604-4940
Research in AI-based techniques for reactive and "anytime" scheduling of combinatorically complex Scheduling problems. Application of that research to Shuttle Orbiter processing at Kennedy Space Center.

Approximate Control for Docking
NASA/ARC, Hamid Berenji, FIA, MS 244-17, (415)604-6070
Research at ARC and UC Berkeley in fuzzy logic and its applications to control of devices and processes. A system has been developed which automatically learns approximate control rules for pole-balancing test problems.

The Next Generation Control System
NASA/MSFC/MMMSS/MAF, M. McGehee/W. LeBlanc/R. Weaver
Configure, Design, Procure, Assembly and program a Lab Prototype of the Next Generation Control System. This system is modular, expandable and utilizes distributed processing and contains a standardized console with programmable touch screen operator interfaces.

Diamond Deposition Control System
NASA/MSFC, F. Roberts, EH34, (205)544-1967
An upgraded DOA,PMD deposition control system has been designed to take advantage of feedback from process variables. The purpose of the software is to use the feedback signals from several of the system components to control the deposition parameters.

Detection of Degradation in Turbomachinery Bearings
NASA/MSFC, Jim McBride, ED23, (205)544-1523
The objectives of the study are to define and develop a reliable method to detect degradation in the performance and operation of high-speed, turbo-machinery bearings, with special emphasis given to the SSME high pressure fuel and oxidizer turbopumps.

Adaptation of Expert System Technology to Enhance Turbomachinery Dynamic Data
NASA/MSFC, Jim McBride, ED23, (205)544-1523
The objective of the study is to adapt the latest expert system techniques to turbomachinery dynamic data analysis to develop an efficient, near real time condition/health monitoring system for STS and NLS launch vehicle engines. The system will provide health monitoring of the engines.

Guidelines and Assistance: AI Design for Human Interaction
NASA/JSC, Jane T. Malin, ER22, (713)483-2046
Develop and provide assistance and guidelines for design of intelligent systems and their user interfaces for effective human interaction, to make automation systems better team players with human operators performing dynamic monitoring and fault management tasks.

Software Technologies for Intelligent Systems
NASA/JSC, Bob Savely, PT4, (713)483-8105
Wide variety of activities associated with evaluating and developing software technologies for use in NASA applications. Many of these technologies may be applicable to Advanced Manufacturing.

Thermal Control System Automation Project
NASA/JSC/MDSSC-SSD, Tim Hill, MDC730K, (713)280-1719
The objective of the TCSAProject is to develop an advanced Fault Detection, Isolation, and Recovery (FDIR) capability for use on the Space Station Freedom (SSF) Active Thermal Control System (ATCS). The primary goal is to control software in order to maximize the autonomy of the ATCS FDIR.

Diagnostic Control by Means of Model Based Reasoning
NASA/JSC/Synetic Corp., Richard Smith/Automation and Robotics Division, (713)737-5505
This project applies the IDEA(tm) (developed at AI squared, Inc.) to a space application; SAREX (Shuttle Amateur Radio Experiment) was the chosen application.

Technical Services Division Computer Aided Manufacturing
NASA/JSC, Mike Hughes, Technical Service Division, (713)483-2250
Technical Services Division (TSD) has the charter for fabrication support of the Johnson Space Center programs. TSD has a continuing program to obtain, install, and utilize the latest technology in computer aided machines for fabrication.

Electronic CAD Workstation
NASA/JSC, Peter Galicki, ER4, (713)483-8086
Electronic design workstation was procured to improve the process of electronic system design and simulation. Intelligent processing by the work- station increased the efficiency of schematic capture and physical layout processes.

SSM/COM Solid Surface Model Object Orientation Manipulator
NASA/JSC, Sharon P. Goza, ER4, (713)483-8451
SSM allows a user to build a 3-dimensional computer graphics model of a design. COM allows the user to animate a 3-D model set in the purpose for which it was designed.

Inexpensive Microcontroller Board With an Integrated C Development Environment
NASA/JSC, Mike Stagnaro, ER4, (713)483-1520
- A low cost microcontroller board based on the z-180 microprocessor. Board includes A/D, D/A, serial and parallel parts, and high current drivers.

CONFIG Integrated Modeling and Simulation Toolkit
NASA/JSC, Jane T. Malin, ER22, (713)483-2046
Integrate modeling and simulation/analysis technologies, from artificial intelligence (AI), especially physical system knowledge representation and reasoning, and from outside AI, to serve application goals: for integrated use and reuse by domain specialists, not just modeling and simulation researchers.

Rendezvous Expert System
NASA/JSC, Hal Hiers, ER2, (713)483-2036
The Rendezvous Expert System had as its objective the demonstration of the application of expert system technology to the Shuttle rendezvous operations. An expert system was developed, integrated with a high fidelity simulation community and Shuttle crew members.

Vacuum Plasma Spray Chamber Handler
NASA/MSFC, W. Neill Myers, EP64, (205)544-7141
A vacuum plasma spray combustion chamber handler has been developed to facilitate the plasma spraying of copper alloy onto the inner surface of the structural jacket of a prototype combustion chamber surface made from high nickel alloy. The part must be rotated and tilted while being sprayed in a vacuum chamber.

Programmable Heater Control Circuit
NASA/MSFC, Donald Bryan, ED64, (205)544-4265
A hybrid integrated circuit (IC) that will integrate the thermal control system and data management system of future spacecraft is being developed. The hybrid combines a microcontroller, serial communications link, dc-dc converter, and a sensor and heater multiplexer into a compact package.

Local Process Controlled Hardware Interface Module (LPC-HIM)
NASA/KSC, Richard A. Nelson, DL-PES, (407) 867-7069
The purpose of this design was to provide local process control of the LC-39 Pad orbiter Environmental Control System (ECS) through existing data acquisition and control channels provided by the Hardware Interface Module commercially available VMEbus components, CPU, Memory and comm cards as well an operating system.

Shared Data Network (SDN)
NASA/KSC, Robert Luken, DL, (407)867-7069
The Shared Data Network is a prototype for a third generation control and monitor system. It shares much of the functionality of CCMS I and CCMS II but improves the scalability, performance, and cost.

Checkout and Monitor System II (CCMS II)
NASA/KSC, F. Byrne, DL, (407)867-7069
CCMS II is a second generation control and monitoring system. It features all the functionality of CCMS but is designed to take advantage of current technology.

Checkout Control and Monitoring System (CCMS)
NASA/KSC, Robert Luken, DL, (407)867-7069
A modular distributed control and monitoring system for real-time applications. The architecture consists of reconfigurable front end modules capable of interfacing to a wide variety of standard and custom data and control interfaces.

Tile Step and Gap System (TSG)
NASA/KSC, Bob Richey, LOSC LSO-151, (407)867-6263
TSG is a Thermal Protection System (TPS) Engineering support system that provides an automated capability for evaluating actual step and gap measurements of installed Orbiter tile against engineering specifications. A computer is used to archive historical evaluation data.

Visual Programming Language
NASA/LaRC, Kelli Willshire,(804) 864-1965
Development of a Visual Programming Language (VPL) which provides a system integration environment. With this VPL, a new configuration can be implemented and tested.

Operations Management Application
NASA/JSC, Rick Eckelkamp, ER2, (713)483-8171
The Operations Management Application is the Space Station onboard software application that provides integrated command and control for station operations. Modules of this application perform the executive tasks that: centralized monitoring of station conditions and operations.

Mission Evaluation Room Advanced Automation Project
NASA/JSC, Ginger Pack, ER2, (713)483-1515
The Mission Evaluation Room Advanced Automation Project is an effort to introduce advanced automation software tools to engineers who must provide support to the Mission Evaluation room during Shuttle Flights. Intelligent analysis of telemetry data received from Orbiter systems is performed.

COMPASS Scheduling AID (SAID) Project
NASA/JSC, Jerry R. Adair, ER22, (713)483-8058
The SAID project was initiated to solve a scheduling problem for the Systems Engineering Simulator (SES). The goal of the project is to reduce the amount of man hours currently being spent on producing a weekly schedule by fifty (50) percent.

Investigation Of Pattern Recognition Techniques
NASA/MSFC, D. P. Vallely, ED14, (205)544-1440
Real time rocket engine failure detection requires rapid ability to detect anomalies by use and correlation of multiple measurements and or very high frequency measurements. The time available for failure response can be as short as 0.1 seconds.

Modular Software For Engine Control
NASA/MSFC, Steve Purinton, EB42, (205)544-3804
The objective of this program is to develop and demonstrate the feasibility of a modular software system that enhances the changeability and verification of SSME controller software with greater efficiency. The approach will use ADA in a real time ground based simulation laboratory.

Electromechanical Servo-Actuators
NASA/MSFC, W. N. Myers, EP64, (205)544-7145
The primary objective of this project is to develop electromechanical type propellant valve actuator technology for large liquid propulsion applications. The current SSME Technology Test Bed uses electrohydraulic as performance degredations.

Solid State Transient Control
NASA/MSFC, D. P. Vallely, ED14, (205)544-1440
Engine starts and shutdown transients are detrimental to SSME hardware, current control techniques use open loop scheduled valve sequences for start and shutdown. Critical parameters such as turbine inlet temperatures and LOX turbopump speeds are not sensed. This program will determine solutions to hardware degradation by developing control logic, techniques and hardware that contribute to increasedlife and lower maintenance of engines

Automated Cylindrical Grinder/Polisher
NASA/MSFC, Jack Phillips, EJ31, (205)544-2199
The ACG/P is used to grind and polish the inside optical surface of the AXAF mirrors. The ACG/P station computer controls the rotation of the mirrors and the motion of the lap tools.

Precision Metrology Station (PMS)
NASA/MSFC, Jack Phillips, EJ31, (205)544-2199
The PMS is used to measure the axial figure of the inside optical surface of the AXAF mirrors. The PMS employs an axial scanning interferometer in combination with a toroidial bar used as a flatness reference to make optical measurements.

Outside Diameter Grinding & Polishing Machine
NASA/MSFC, Jack Phillips, EJ31, (205)544-2199
The ODGM is used to grind, polish and measure the outside surface of mirrors used in the AXAF. The tool stroke and frequency, mirror blank rotational speed and measurements are computer controlled.

Real-Time Engine Safety Monitor
NASA/MSFC, Stanley E. Douglas, ED14, (205)544-4513
The objective of this program is to develop and validate a real time rocket engine safety monitoring system for use on the SSME Technology Test Bed Engine. This ground test safety system will be able to monitor delta systems purposes of evaluation of the new logic, and will be able to run with and without engine shutdown authority.

Vacuum Plasma Spray Process
NASA/MSFC, Jeff Ding / EE24, (205)544-2700
The Vacuum Plasma Spray Process is a method of forcefully injecting a fine, ultra-pure powdered materials into a high temperature plasma of argon and hydrogen which is generated from ionizing gas thru the plasma arc. The result of the process is a build-up of material on the substrate. Materials can be metals, non-metals, or mixtures.

Fault Management Decision Aid (Faultfinder)
NASA/LaRC, Paul Schutte, Human/Automation Integration Branch, (804)864-2019
This fault management decision aiding concept is designed to aid flight crews of civil transport aircraft in managing inflight subsystem failures. It has four functions: monitoring, diagnosis, recovery recommendation, and operator interface.

Development and Validation of Highly Reliable Knowledge-Based Systems
NASA/LaRC, S. Johnson/MS 130, (804)864-6204
Because current techniques are insufficient for developing and validating highly reliable knowledge-based systems for life-or-mission-critical applications, more rigorous methods were explored. A method for specifying minimum safety requirements was proposed.

Operation Mission Planner
NASA/JPL, Eric Biefeld, MS 301-490, (818)306-6131
Develop an automated resource scheduling system using artificial intelligence techniques for application to spacecraft, ground systems, and other types of scheduling problems. A system has been developed based on a multi-pass scheduling process called interleaved iterative refinement.

Selective Processing in Monitoring
NASA/JPL, Dr. Richard Doyle, MS 301-490, (818)306-6131
Development of monitoring software which can maximize feedback of critical engineering information to operate personnel from systems having thousands of sensors. The goal is to avoid information overload, reduce comprehension and devices being monitored.

Neural Network Hardware Technology
NASA/JPL, Dr. Anil Thakoor, MS 302-231, (818)354-5557
The artificial neural network hardware development effort encompasses electronic and optoelectronic implementations. This effort is leading to highly parallel, reconfigurable, application-specific, analog neuroprocessors easily tackled by conventional digital computing technologies.

Remote Exploration and Experimentation Task
NASA/JPL, Dr. John Davidson, MS 198-231, (818)354-7508
Provide an approach and methodology for projecting performance of proposed computer architectures, given a characterization of the workload. A particular emphasis is placed on modeling the performance of multi-processors.

Engineering Analysis Subsystem Environment Prototype (EASE)
NASA/JPL, Dr. K. Bahrami, MS 303-300, (818)354-9032
EASE is a collection of software programs on networked computer workstations intended to support multiple, simultaneous spacecraft mission operations while requiring fewer human analysts. EASE is for conducting analyses including telemetry monitoring for spacecraft health and safety, sequence expansion, validation, calibration, maneuver design, and tracking of consumables.

Neural Network Based Power System Management and Control
NASA/JPL, Dr. H. Kirkham, MS 303-300, (818)354-9699
The potential of neural network techniques to solve electric power system security assessment tasks under real time constraints is being studied. In order to classify power system operating states, a simulator of the self- has been interfaced with existing power system analysis software.

Encyclopedia for Software Components
NASA/JPL, Dr. Brian Beckman, MS 301-490, (818)354-1252
The ESC, or Encyclopedia of Software Components, is a software cataloging and retrieving system based on hypertext, hypergraphics, and an electronic metaphor of an encyclopedia. The encyclopedia organizes a large collection of software into a dynamically cross-linked hierarchy of knowledge.

Link Monitor/Control Operator Assistant: Application to Deep Space Network
NASA/JPL, Lynne Cooper, MS 525-3660, (818)306-6145
The Link Monitor & Control (LMC) Operator Assistant (OA) prototype is an artificial intelligence-base system designed to assist Deep Space Network (DSN) operators in monitoring and controlling the DSN link resources interplanetary spacecraft.

Mini-Rover Science Demonstration
NASA/JPL, David Miller, MS 525-3660, (818)306)6172
The Mini-Rover Science Demonstration Task develops, integrates, validates and demonstrates the functionality of small rovers performing scientifically useful tasks. The small rover uses a "behavior control" which has very low communication requirements, allowing the rover to be small.

Knowledge-Based System for Continuous Mix Control
NASA/MSFC/Lockheed, Al Brown, (916)355-5965
A knowledge-based control system is under development to control the mixing of solid propellant for the advanced solid rocket motor processing.

Self-Stable Magnetic Suspensions and Bearings
NASA/MSFC, P. Peters, MS ES63, (205)544-7728
High temperature superconductors combined with rare-earth magnets have been demonstrated to provide stable suspensions and bearings. These systems are self stable and maintain a nearly constant separation for a given set of system parameters.

NATIONAL INSTITUTES OF HEALTH
PRESENTATION AT IPE CONFERENCE PROGRAM

by

Dr. Caroline Holloway
Director, Office of Science Policy
National Center for Research Resources
National Institutes of Health
Bethesda, MD 20892
(301) 496-2992

The objective of this conference is to set up a working dialogue among representatives from industry and various Federal agencies. As the representative from the National Institutes of Health (NIH), I would like to focus first on present NIH support in the area of intelligent processing equipment (IPE) and then to explore with you how we can work together on future research objectives.

Before I tell you about NIH research related to IPE, I must offer several caveats. To prepare for this talk, I reviewed abstracts of NIH research for FY 1990 and 1991 related to this topic. Within the limits of the IPE definition--"federally developed innovations in robotics, sensors and controls that industry can apply to a broad range of manufacturing processes including: machining, forming, welding, heat-treating, inspection and assembly"--NIH is currently **supporting ONLY ONE** project that is directly relevant and possibly a few others that are indirectly. These are listed in the survey of FY 1990 and 1991 NIH research relevant to IPE/advanced manufacturing provided for this program.

Another caveat is that from NIH's perspective, one of the most advanced pieces of **intelligent processing equipment** is not a new sensor or a new robot or a new electronic control system but is rather **the genetically engineered mammary tissue from a variety of common farm animals**--cows, pigs, and goats. Such tissue has now been programmed--genetically engineered, if you like--to inexpensively produce a number of important, very expensive **human proteins** for the cost of farm animal feed! The proteins are easy to isolate from milk, appear to be highly specific and reliable, and entirely compatible with human needs.

Now let me focus on the subject of this conference--the NIH support and interest in intelligent processing equipment. First, I have several slides which will help me to provide you with a brief overview of the National Institutes of Health.

SLIDE 1: NIH MISSION STATEMENT (Attachment A)

Science in pursuit of knowledge to extend healthy life and reduce the burdens of illness or disability.

SLIDE 2: NIH ORGANIZATIONAL CHART (Attachment B)

Note the diversity of the NIH organizational structure--Institutes, Centers, and Divisions--21 in all--each with specific missions subsumed under the overall NIH mission. The Institutes range in size from the largest--Cancer; Heart, Lung, and Blood; and Allergy and Infectious Diseases to the smallest--Deafness and Other Communicative Disorders and Dental. Both extramural and Intramural components are contained within most of these entities.

SLIDE 3 NATIONAL CENTER FOR RESEARCH RESOURCES (NCRR) ORGANIZATIONAL CHART (Attachment C)

I am the director of the Office of Science Policy for the National Center for Research Resources (NCRR), one of the many components of the NIH. The NCRR is responsible for providing support for the research resource needs of the NIH Institutes' extramural programs throughout the world and also their intramural programs at our headquarters in Bethesda, Maryland.

An NCRR extramural component, the **Biomedical Research Technology Program (BRTP)**, has the responsibility to develop and support advanced technologies that are essential for the NIH mission. Today, the program focuses on biomedical computing, biomedical engineering, and technologies for the study of molecular and cellular structure and function. BRTP funds technology development through a variety of grant and contract mechanisms. For instance, there are **resource centers, investigator-initiated research grants, pilot projects for innovative technology and small business innovation research grants. Later in this talk, I will describe two IPE projects supported by the BRTP.**

At NIH the focal point for engineering and related sciences is an NCRR intramural component, the **Biomedical Engineering and Instrumentation Program (BEIP)**. The BEIP staff of about 35 professional engineers with five additional physical scientists and mathematicians collaborate and consult on about 160 major projects annually with NIH biomedical investigators on applications of engineering, mathematics, physics, and the physical sciences. Specialties include chemical, mechanical, electrical and applied clinical engineering. In addition, BEIP research projects are also conducted with members of the extramural research community at universities and other research institutions as well as in conjunction with industry using the CRADA (collaborative research and development agreement) mechanism.

In my survey of NIH research, I selected two BEIP projects. One is of marginal IPE interest at the present time; the other, an array-type multiple cell injector, is still in the early stages of development. This instrument will be used to inject a large number of biological cells simultaneously with substances such as DNA or RNA. The device automates the task, making it reliable and simplified. The array is passed through a liquid suspension of cells. The cells filling the array are positioned on a rectangular grid of holes, each sized to contain a single cell. The holes are connected to a vacuum manifold which provides differential pressure to keep the cells in place. Once positioned, the cells can be injected by one of two ways--by repeated injection from a single pipette or on a matching "bed-of-nails" injecting all cells at once. The array of holes is micro-machined so that 10,000 10-micron diameter cells can be held in a regular array of 2 mm on a side. This device has applicability to biotechnology and pharmaceutical industry needs.

SLIDE 4 ARRAY-TYPE MULTIPLE CELL INJECTOR (hard copy not available)

This slide shows an array of only a few 0.5 mm diameter holes for holding 1.0 mm diameter frog eggs. This is only an early prototype. This project's investigators are currently looking for an industrial CRADA partner to further develop this and other related devices.

The **potential exits for BEIP to collaborate with industry** by providing both highly qualified staff and interesting biomedical problems. I hope we can explore this potential through further discussions as the conference continues.

Let me proceed by briefly summarizing how the research interests of some of the other NIH entities are structured. As we saw on the first slide, many NIH entities are focused around a disease, organ system or a process and, of course, their research support is consistent with that mission. The National Institute of General Medical Sciences, on the other hand, supports non-disease-targeted research in the basic biomedical sciences that are of broad interest to the NIH. All use either the research project grant mechanism or the small business grants to support their extramural research interests.

Now, let me turn to extramural **support** for IPE-related research. Most of the examples I found in my search of the NIH database can be described as having **Sensor Development or Refinement as the goal.** One set of examples, supported by the National Institute of Allergy and Infectious Diseases, involves biosensors used to rapidly and accurately detect antibodies to infectious agents such as the AIDS virus, toxins or drugs in blood or other body fluids. The safe and effective processing of blood for a variety of commercial processes or manufacture could be impacted by such research.

The National Institute of General Medical Sciences also supports sensor development or refinement. Examples include sensors for glucose, pH, pCO2, pO2, and other biologically relevant gases; and miniature hybrid sensors that detect, for example, temperature and oxygen in continuous perfusion systems. An interesting sensor is being developed that allows the detection of the mass of the entire tissue using individual cells within the tissue as markers.

I have placed other IPE relevant projects supported by the NIH in the category of **Unique Devices.** One such device that might be of interest for industrial development is supported by the National Cancer Institute. It is a simple hand-held, battery-operated device to detect carbon monoxide on the breath. This device could have an impact on providing a safer environment in the workplace.

From our NCRR BRTP Program, I would like to describe a project uniquely related to IPE--the **Resource Center for Biomedical Sensor Development** at Case Western Reserve University. This Resource has five objectives: core research, collaborative research at the regional and national level, service, training and dissemination.

This center has an advanced microfabrication facility--a Class 100 clean room microfabrication facility with silicon. It is **supported by funds from the NCRR, Case Western Reserve, the State of Ohio, private foundations and industrial contributions.** The Resource does core development on new materials and sensors, tests for efficacy and usefulness, and, in the case of sensors used invasively, tests for biocompatability. The Resource investigators collaborate with investigators throughout the country and, of course, work closely with industry and other government agencies such as NSF and NASA. One example of their collaborative efforts is the NSF-sponsored Center for Emerging Cardiovascular Technologies at Duke University.

It is within the context of this type of resource center that new IPE opportunities could be developed. NCRR resource centers and related technology research are a dynamic vehicle for partnership with industry and with other Government agencies. Our long experience in such cooperative ventures has been extremely successful and can be expanded in this area of intelligent processing equipment. Suggestions for future collaborations and projects are welcome. If you are interested, we have some excellent publications on our programs available in booth 228 at the Exposition.

The last project I wish to describe is the most relevant to the IPE initiative and that is the integrated multirobot system for laboratory automation. This project is supported by NCRR under the Small Business Innovation Research Program.

Let me begin by stating that although great strides in robotics have been made over the past decade, there is still a significant need for further research to fully realize the potential of this technology in biomedical areas. This particular project was supported because it addressed some of the limitations, explored innovative robot configurations, and could be applied to robotics for biomedical research.

The RobotWorld system uses multiple cooperating robotic modules that share the same workspace and combine advanced vision sensing with a novel configuration and very high accelerations and accuracies. I will show you a brief video to demonstrate the first phase of this project. Some examples of possible industrial targets are: blood processing and screening labs,
pharmaceutical labs, and the food industry.

Show Video of RobotWorld Project

At this time, I will be glad to answer any questions concerning this presentation. Mr. Agapakis of Automatix, Inc. is here in the audience and he would be glad to discuss any questions you might have on their integrated multirobot system.

NIH Mission Statement

Science in pursuit of knowledge to extend healthy life and reduce the burdens of illness or disability.

(Revisions as of 9/10/91)
NCRR 9/91

ATTACHMENT B

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
National Institutes of Health

Sept. 1991

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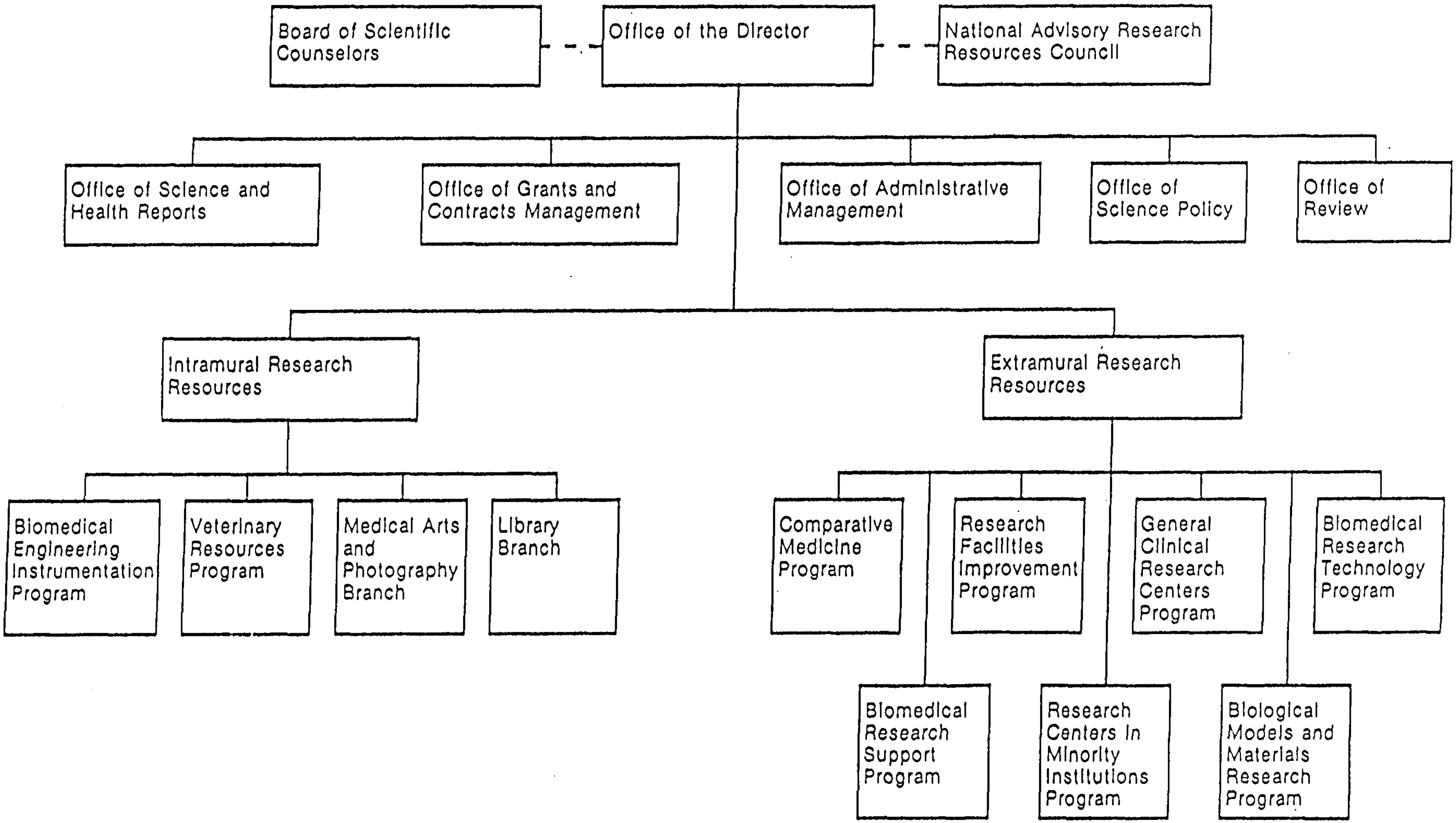
ATTACHMENT C

National Center for Research Resources



NATIONAL INSTITUTES OF HEALTH
FY 1990 AND FY 1991 NIH-SUPPORTED RESEARCH RELEVANT TO INTELLIGENT PROCESSING EQUIPMENT/ADVANCED MANUFACTURING

Recently, staff of the National Center for Research Resources, NIH collected and reviewed data on FY 1990 and 1991 NIH-supported research in the area of Intelligent Processing Equipment (IPE) focusing on Advanced Manufacturing Technology. The IPE definition--federally-developed innovations in robotics, sensors and controls that industry can apply to a broad range of manufacturing processes including machining, forming, welding, heat-treating, inspection, and assembly--was broadened to include research in biosensors and electrodes. This was done for two reasons. First, with only one exception, NIH is not presently funding any research that is directly related to the specific areas mentioned in this particular definition. Secondly, by broadening the definition, data could be included that would be of interest to industries concerned with the manufacture of pharmaceuticals, drug development or the production of biologicals.

The 17 projects described below were selected from more than 200 projects on biosensors and bioelectrodes supported by NIH in FY 1990 and 1991. These have been put into two categories: sensor development and refinement and unique devices. The majority of NIH support for biosensors and electrodes is concerned with direct biomedical or clinical applications.

CATEGORY: SENSOR DEVELOPMENT AND REFINEMENT

Richard O. Roblin R44 AI26019
Biotronic Systems Corporation
15225 Shady Grove Road
Rockville, MD 20850
Rapid Biosensor Assay of AIDS Virus Antibodies

This grant is for the development of a rapid biosensor assay for antibodies to the AIDS virus. This rapid, multianalyte biosensor system can rapidly and simultaneously detect antibodies to antigens of infectious agents, and uses an "electronic Western Blot" approach. Agents such as hepatitis B and HIV could be detected. This is an innovative bioelectronics technology useful to blood banks and for organ transplantation. This impacts on IPE because the production of safe blood products is a very important commercial venture for both human and animal uses. The ability to rapidly and accurately assess the safety of blood fluids for a wide variety of agents before processing the blood for commercial product extraction would make a significant contribution to this industry.

Richard Smith R44 AI26438
BIOQUANT, INC.
1919 Green Road
Ann Arbor, MI 48105
Solid State Enzyme-Based Immunosensors

This grant is to develop solid state enzyme immunosensors. An enzyme-amplified, immunoelectrochemical solid phase detector is coupled to a reporter-amplification system. In this method, a sample is injected using a one-step operation--a disposable cartridge--and eliminates the need for pipetting samples. Samples are only injected at the beginning of the process. This process could be used to detect toxins, infectious agents, drugs and a variety of diagnostics in blood, saliva and urine. Positive results from this study would be of use in processing blood for commercial product extraction.

James Zull R01 GM45687
Case Western Reserve University
Cleveland, Ohio
Electronic Sensor for HIV Antibodies

This grant is to develop a fast response, simple-to-operate immunosensor for HIV antibodies.

Willfried Schramm R43 DA06344
BIOQUANT INC.
1919 Green Road
Ann Arbor, MI 48105
Immunosensor for Drug Monitoring

This grant is to develop an immunosensor for drug monitoring (human) assay in 3 to 5 minutes.

S. Sarangapani R44 DK39923
Giner Inc.
14 Spring Street
Waltham, MA 02254-9147
Glucose Sensor with Improved Stability

This grant is to develop a glucose sensor with improved stability and to optimize electrode structure and stability.

Paul Hale R43 DK42379
Brookhaven National Laboratory
Upton, N.Y. 11973
Amperometric Glucose Sensor

This grant is to develop a amperometric glucose sensor with redox polymer mediators--a new class of amperometric glucose sensors.

Philip R. Troyk R01 GM39960
Illinois Inst. of Technology
IIT Center
Chicago, IL 60616
Polymeric Protection of Implantable Micro-electronics

This grant is to develop polymeric protection of implantable microelectronics. Packaging of chronically implantable micro-electronic integrated circuits.

Mark E. Meyerhoff R01 GM28882
University of Michigan
Ann Arbor MI 48109-1055
Polymer Membrane Based Gas and Anion Sensors

This grant is to develop a new tubular gas sensing catheter for continuous in vivo monitoring of pC02. Also includes studies of a new stop-flow/flow-injection arrangement for enhancing the sensitivity of automated polymer electrode-based gas detectors. This concept will be examined in the design of ambient NH3, N02 and S02 sensors.

Theodore R Beck R44 GM36220
Electrochemical Technology Corporation
1601 Dexter Ave N
Seattle, Washington 98109
Development of Optical Sensors Based on a New Membrane

This grant is to develop optical sensors based on a new membrane. The unique combination of chemical and optical properties of a new class of acrylic ion-transfer polymers will be exploited to develop a family of miniature, disposable optical sensors for pH, pC02 and p02.

Richard H. Gomer R01 GM42604
Rice University
Houston, TX 77251
A Eukaryotic Tissue Density Sensor

This grant is to develop a eukaryotic tissue density sensor in the model system, dictyostelium discoideum. This proposal concerns eukaryotic mass effectors--extracellular molecules that allow individual cells within a tissue to sense the mass of the entire tissue.

Michael G Curley R44 HL42199
Thermal Technologies, Inc.
222 3rd St. Suite 123
Cambridge MA 02142
Continuous Oxygen Tension--Perfusion Measurement System

This grant is to develop a continuous oxygen tension--perfusion measurement system. Prototype design and testing of a miniature hybrid thermistor/polarographic sensor for tissue oxygenation and perfusion studies.

A.C. McLauglin Z01 AA00041
National Institute of Alcohol
Abuse and Alcoholism (NIAAA)
Alcohol, Drug Abuse and Mental Health Admin. (ADAMHA)
Determination of Plasma Free Magnesium Concentration by Ion-Selective Electrodes

This intramural project is to determine plasma free magnesium concentration by **ion-selective electrodes.**

H.E. Cascio Z01 RR10267
National Center for Research Resources
National Institutes of Health
Bethesda, MD. 20892
A Low-Noise Electrometer for an Automated OEC Measurement System

This intramural project is to develop a low-noise electrometer for automated measurement of the hemogloblin oxygen equilibrium curve; partial pressures read reliably with an accuracy of 0.01 mmHg in an environment contaminated by radio frequency interference and magnetic fields. The project requires special techniques in electronic circuit design.

Chung-Chiun Liu P41 RR02024
Case Western Reserve University
10900 Euclid Avenue
Cleveland, OH 44106
Resource Center for Biomedical Sensor Technology

Core research includes electrochemical sensors, gas sensors, chemical microsensors, on-chip reference electrodes, silicon capacitive transducers for physiologic control, thermal sensors for tissue perfusion, miniaturized chamber-type sensors. Resource capabilities include: Class 100 microfabrication laboratory, silicon-based fabrication facilities, machine shop, electronic shop, pathology laboratory, and microelectronic and electrochemical laboratory.

CATEGORY: UNIQUE DEVICES

John E. Agapakis R43 RR06689
Automatix Inc.
755 Middlesex Turnpike
Billerica, MA 01821
Integrated Multi-Robot Systems for Laboratory Applications

The RobotWorld system of multiple, cooperating robotic modules that share the same workspace was developed by Automatix and combines advanced vision sensing with novel configuration and very high accelerations and accuracies. This grant is to establish the feasibility of using multiple robots in either robotic or remotely operated modes for performing laboratory operations. The research will also identify the areas most applicable to multi-arm manipulation capabilities; analyze laboratory tasks and how they can be adapted to use multiple robots; and identify the inherent multitasking possible with this system.

Peter Basser Z01 RR10274
National Center for Research Resources
National Institutes of Health
Bethesda, MD 20892
A Non-invasive Method to Measure and Monitor Contact Stress in Tissue

This device will measure and monitor contact stress by using polyelectrolyte gel and an NMR pH indicator. The device has long-term stability, contains no cytotoxic substances or chemicals in nonphysiologic concentrations, and is not toxic to surrounding biological tissue.

Joseph Stetter R43 CA50009
Transducer Research, Inc.
1228 Olympus Drive
Naperville, IL 60540
Simple measurement of carbon monoxide on the breath--small hand- held battery-operated device

CODES:

AA National Institute on Alcohol Abuse and Alcoholism
AI National Institute of Allergy and Infectious Diseases
GM National Institute of General Medical Sciences
DA National Institute of Drug Abuse
DK National Institute of Diabetes and Digestive and Kidney Diseases
HL National Heart, Lung and Blood Institute
RR National Center for Research Resources
P41 Biotechnology Resource Grant
R01 Research Project Award
R43 Small Business Innovation Research Grant-Phase I
R44 Small Business Innovation Research Grant-Phase II
Z01 Intramural Research Projects

INTELLIGENT PROCESSING EQUIPMENT RESEARCH SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

by

Suren B. Rao
Program Director
Division of Design and Manufacturing Systems
NSF, 1800 G Street NW
Washington D.C. 20550

ABSTRACT

The National Science Foundation (NSF) has been supporting basic research in the nation's academic institutions to develop the theoretical understanding and knowledge base for the "next generation" of intelligent materials processing and manufacturing systems. The research in progress on processes, workstations and systems, has the goal of developing a high level of understanding of the issues involved. This will enable the incorporation of a level of intelligence that will allow the creation of autonomous manufacturing systems that operate in an optimum manner, under a wide range of conditions. The emphasis of the research has been the development of highly productive and flexible techniques to address current and future problems in manufacturing and processing. Several of these projects have resulted in well- defined and established models that can now be implemented in the application arena in the next few years.

INTRODUCTION

The NSF was established in 1950 to support basic scientific research in science and engineering and the related education and human resource training. Though not specifically mandated, the NSF has been expending a majority of it's resources at the nation's institutions of higher learing. This is accomplished by the funding of grants for research projects that are selected by the Foundation through a peer review process. Most of these awards are in response to either unsolicited proposals or proposals received in response to special initiatives that are planned and announced, in response to national needs, that may arise from time to time.
The NSF, under the stewardship of a Director and Deputy Director who are appointed by the President, is organized into seven Directorates. Within each directorate are divisions that focus on one or more functional areas in science and engineering. Figure 1 shows the current organizational structure. These divisions are further divided into specific program areas. The divisions and program areas are created, modified or disbanded as necessary, on the recommendations of a host of advisory groups that advise the NSF staff at all levels. The members of the advisory committees are generally drawn from among the leaders of education and industry. The highest level advisory group to the NSF is the National Science Board, which is appointed by the President with the advice and consent of the Senate and the Director of the NSF. Advisory groups also exist at the Directorate and Division level to steer the program activities of the Foundation to meet national needs.

The steadily growing crisis that the nation faces in the general area of manufacturing and materials processing has resulted in a growing emphasis on NSF sponsored research in this area. There have been thrusts to initiate projects that will bring to light the fundamental processes involved in the entire phenomenon of manufacturing and material processing. This not only includes the physical process or processes involved but all the ancillary and auxiliary functions that are inherent and essential to the phenomenon. This will enable the development of the "next generation" of intelligent, autonomous workstations and systems that can operate at optimum and therefore economical conditions, even when subjected to a wide variety of disturbances and changes. The basic understanding and knowledge base being developed could have far reaching consequences for the nation's manufacturing enterprise and it's competitive ability, ultimately enabling the development of Intelligent Processing Equipment (IPE). In addition, the support of such activities in the nation's academic community, ensures the availability of human resources that are knowledgable in manufacturing and processing for the next generation and beyond.

Several new initiatives are also planned for the near-term and long-term. They include the Advanced Material Synthesis and Processing initiative to create, develop and expand the scientific and engineering foundations of synthesis and processing methods for new and existing materials. Also in the initial stage is the Advanced Intelligent Manufacturing Systems initiative. In this initiative it is proposed to develop a fundamentally different approach to the issues related to manufacturing by bringing to bear the tremendous advances in computer and information science on problems in manufacturing.

A survey of activities at the NSF that are related to the development of IPE resulted in the identification of 112 projects that are currently supported or which have been supported in the recent past. Of these only about 12% were in the category of robotics with the remaining projects in the category of sensors and controls. They were found to be predominantly in the Directorates for Engineering (ENG), Computer Information Science and Engineering (CISE) and Mathematical and Physical Sciences (MPS). A brief description of the activities that are being supported in each of the directorates follows.

DIRECTORATE FOR ENGINEERING

A significant portion of support for all the activities in the realm of IPE in the foundation is provided by this directorate. These efforts are primarily concentrated in the Division of Design and Manufacturing Systems (DDM), the Engineering Centers Division (ECD) and the Division of Chemical and Thermal Systems (CTS).

DDM projects are focussed in discrete parts processing involving a range of unit processes. This includes projects to develop a fundamental understanding of unit processes that result in mass-change, phase-change, deformation, consolidation or structure-change. Inspection is also considered. Examples of such processes are metal cutting, metal forming, joining, casting, heat treatment, polymer processing, processing of composites, processing of ceramics and the manufacture of electronic materials and devices. Studies to process materials on the atomic scale are also a major thrust within this group with emphasis on scanning tunelling microscopy and associated modeling through molecular dynamics to establish the theoretical and fundamental knowledge base. As stated before, the development of a fundamental understanding of these processes will enable the implementation of a level of intelligence in the processing equipment so that the process is always under control and operating at the optimum and economical conditions.

From the processing equipment perspective, the focus is usually to increase throughput at lower cost while reducing variability of part properties. Since the impediments to higher throughput and lower variability are functional instability of the equipment and process related instability of the unit process, in it's interaction with the equipment, research being supported is designed to understand the fundamental causes of these instabilities. This knowledge will pave the way to develop design principles for future generation equipment. If such instability is unavoidable, the knowledge of the causes will be used to design and build intelligent processing equipment to avoid and compensate for such instability, if it should occur. Recently developed techniques such as Artificial Intelligence (AI) and Artifical Neural Networks (ANN) are being applied to achieve this end. The ultimate objective is to develop the fundamental principles that will enable the development of high speed, high stability, autonomous equipment that can operate at optimum processing conditions and produce very high quality parts and assemblies.

System related issues are also being addressed through projects in the area of Operations Research and Production Systems. Projects are also supported, in DDM, on design-related issues such as design for manufacturability and concurrent engineering within the Computer Integrated Engineering and Engineering Design programs. While these projects are in the area of manufacturing sytems, efforts in areas such as intelligent material handling systems are often structured with strong potential impact on the design and utilization of processing equipment.

The ECD supports research in manufacturing that has significant impact on IPE through the Engineering Research Centers (ERC) program and the Industry University Cooperative Research Centers (IUCRC) program. Prominent among the ERCs that are carrying out research activities in manufacturing are the Net Shape Manufacturing Center at the Ohio State University. This center focusses on the cost-effective manufacture of discrete parts. Its research spans all stages of manufacturing from engineering materials to finish or near-finish dimensions by melt processing (casting, injection molding), shaping from powder, forming from sheet and forming from billet. The Engineering Research Center for Intelligent Manufacturing Systems at Purdue University is another outstanding example of research activity supported by ECD that is related to IPE. The research activity is concentrated on all technical activities in manufacturing of discrete products from early design to completion. The Engineering Design Research Center at Carnegie Mellon University, the Systems Research Center at the University of Maryland, the Center for Plasma-Aided Manufacturing at the University of Wisconsin-Madison and the Center for Advanced Electronic Materials Processing at North Carolina State University are other centers supported by the ECD to contribute a fundamental knowledge base with significant impact on IPE. Industry interaction and support is stressed and strongly encouraged in the ERCs through coalition membership and industrial advisory groups. Educational and other forms of outreach is also supported to address the human resource issues that are fundamental to our ability to be competitive in the international arena.

The overall focus of the IPE related research, in the CTS division, is automation of the design and control of chemical manufacturing facilities and other forms of continuous bulk processing. Research in non-linear control, multivariable control, practical adaptive control and self-learning control, robust control, routine methods of fault diagnosis, design of separation sequences and reactor networks are integral part of the supported effort. Special emphasis is placed on the use of AI and Expert Systems to deal with large-scale systems as well as the adaptation of new technologies such as neuro-engineering and parallel processing to process control problems.

DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING

Activities supported in this directorate were predominantly in the Division of Information, Robotics and Intelligent Systems. Support for research in this division seeks to increase scientific knowledge of information processes in machines and complex systems. Central to the understanding of these processes are the properties of symbolically interpreted representations and the dynamics of their propogation and aggregation. Five sub-topics are evident. They are; a) Database and Expert systems, b) Information Technology and Organization, c) Interactive Systems, d) Knowledge Models and Cognitive Systems and e) Robotics and Machine Intelligence.

A significant number of IPE activities in this division was in the program area; Robotics and Machine Intelligence. Research is being supported that is fundamental to the design of systems capable of implementing some of the characteristics ofintelligence. Research topics include pattern recognition, machine vision, speech understanding, sensor-based control in intelligent robots and automatic reasoning and planning of complex tasks involving temporal and spatial relationships in robotic and other computer systems.

Research fundamental to knowledge representation and to the design of computer systems for reasoning and problem solving are supported by the Knowledge Models and Cognitive Systems program. Research topics include formal models of information, knowledge and reasoning, natural language processing and cognitive systems problem solving and learning.

The Interactive Systems program, the Information Technology and Organizations program and the Database and Expert Systems program also support research that is related to IPE.

DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES

Activities in this directorate that could impact IPE are concentrated in the Division of Materials Research. This directorate supports research that is aimed at developing a fundamental understanding of the physical laws that govern the universe. The Division of Materials Research (DMR) focusses on supporting materials research. Four major sub-topics are evident. They are: a) Condensed Matter Physics, b) Solid State Chemistry and Polymers, c) Metals, Ceramics and Electronic Materials and d) Materials Theory.

Though most of the work supported in this division could eventually end up in process models that would assist the development of IPE, most of the effort that could have direct impact was in the Metals, Ceramics and Electronics Materials program. This program supports work on fundamental research in metals, ceramics and electronic materials and includes the required theoretical and computational research support. The primary objective is to increase knowledge and predictive capabilities related to the effects of chemistry, processing and microstructures on the properties and performance of these materials. Understanding of the influence of the environment on these materials is also supported. In the Solid State Chemistry and Polymers program the supported work is focussed on the physical and chemical behavior of polymers, which is of significant industrial and commercial relevance. Research in the Materials Theory program could also be of long term importance to the IPE field.

CONCLUSION

As evidenced by this synopsis and the supporting data the National Science Foundation, in a modest fashion, supports cutting-edge, long-term research in the IPE domain that could have a significant impact on the nation's industrial competitiveness. Key to this support activity is the training of human resources. By supporting such research in institutions of higher learning, it ensures the supply of the next generation of scientists and engineers skilled in the technologies that will power such equipment and maintains the viability of our industrial infrastructure in the near and distant future.

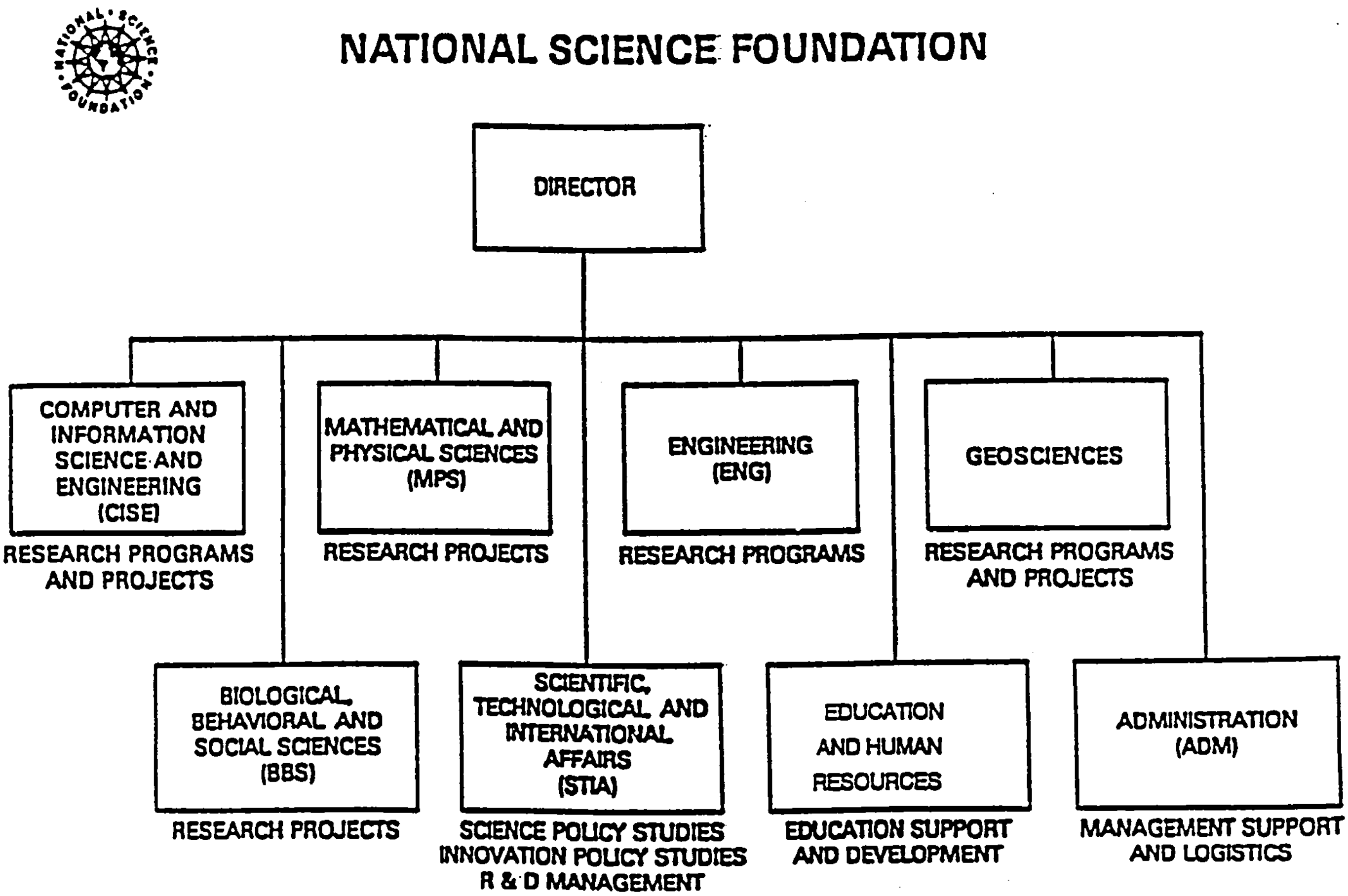

NATIONAL SCIENCE FOUNDATION
DIRECTOR
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE)
RESEARCH PROGRAMS AND PROJECTS
MATHEMATICAL AND PHYSICAL SCIENCES (MPS)
RESEARCH PROJECTS
ENGINEERING (ENG)
RESEARCH PROGRAMS
GEOSCIENCES
RESEARCH PROGRAMS AND PROJECTS
BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES (BBS)
RESEARCH PROJECTS
SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS (STIA)
SCIENCE POLICY STUDIES
INNOVATION POLICY STUDIES
R & D MANAGEMENT
EDUCATION AND HUMAN RESOURCES
EDUCATION SUPPORT AND DEVELOPMENT
ADMINISTRATION (ADM)
MANAGEMENT SUPPORT AND LOGISTICS

Figure 1

INTELLIGENT PROCESSING EQUIPMENT RESEARCH SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

CATEGORY: ROBOTICS

New Agorithmic Techniques for Task-Level Robot Planning.
Bruce R. Donald, Cornell University.

Information-Based Task-Level Planning.
Michael A. Erdmann, Carnegie Mellon University.

Intelligent Materials Handling Systems: Mobile Manipulation: Intelligent Sensor-Based Robotic Strategies for Material Handling.
Ronald Arkin, Georgia Institute of Technology.

Integrated Modeling and Control for Intelligent Material Handling.
O.R.Mitchell, University of Texas-Arlington.

Robotic Grasping and Manipulation.
M.Cutosky, Stanford University.

Strategies for Generating Large Cartesian Velocities of Two Serially Connected Robots.
Y.F.Zheng, Ohio State University.

Automatic Fixture Design for Robotic Assembly: Issues and Current Trends.
Lucy King, General Motors Institute

High Performance Linear Induction Motor-Based Material Mover.
Neil Duffie, University of Wisconsin-Madison.

Robot Mobility Within a Manufacturing Cell.
Gloria Wiens, Auburn University.

Thermoplastic Matrix Fiber Composite Materials: A Small Machine for Die-Less Forming of Large Components.
Alan Miller, Stanford University.

Design and Control of Multi-Degree-of-Freedom Vehicles for Industrial Applications.
Johann Borenstein, University of Michigan.

An Enabling Environment for Design and Control of Intelligent Material Handling System.
Udatta Palekar, University of Illinois-Urbana.

CATEGORY: SENSORS

Ceramic Machining Flaw Detection.
John Mayer, Texas A&M.

In-Situ Measurement of Transient Polymer Melt Temperatures via Infrared Pyrometry during Injection Molding.
Jeroen Rietveld, University of Wisconsin-Madison

Computer Aided Design for Casting and Solidification.
John Berry, University of Alabama.

Development of a System for In-Process Characterization of Properties and Forming Characteristics of Copper Alloy Strip.
Clayton Rudd, Pennsylvania State University.

In-Process Identification and Correction of Weld Perturbations.
Bryan Chin, Auburn University.

Optimization of Feedback Control in Sheet Metal Forming:The Intelligent Forming Die.
Klaus Weinmann, Michigan Technological University.

Dynamic Dielectric Monitoring of In-Situ Consolidation of Thermoplastic Filament Winding.
Steven Liang, Georgia Institute of Technology.

Interreflection Analysis for Machine Vision.
Shree Nayer, Columbia University.

Parallel Algorithms for Intelligent Imaging and Vision at Low Signal to Noise Ratio.
Badrinath Roysam, Rennselaer Polytechnic Institute.

Color Image Enhancement and Segmentation for Computer Vision.
Jeffrey Rodriquez, University of Arizona.

Development of New Back-Propogation Morphological Algorithms and Architectures.
Frank Shih, New Jersey Institute of Technology.

Computer Visual Analysis of Surface Reflection.
Ruzena Bajcsy, University of Pensylvania.

Polarization Methods in Machine and Computer Vision.
Lawrence Wolff, Johns Hopkins University.

Understanding the Dynamics of 3-Dimensional Shape Appearance.
Charles Dyer, University of Wisconsin-Madison.

Color Segmentation of Images of 3-Dimensional Scenes.
Glenn Healey, University of California-Irvine.

Automated Model-Based Computer Vision.
Linda Shapiro, University of Washington.

Knowledge-Based Sensor Integration.
Ellen Walker, Rennselaer Polytechnic Institute.

Extending the Capabilities of Robotic Systems.
Peter Allen, Columbia University.

Research on Design Evaluation of Image Processing Systems for Pattern Recognition.
Kendall Preston, Carnegie Mellon University.

Neural Network Architecture for the Direct Perception of 3-Dimensional Motion and Depth.
Laveen Kanal, University of Maryland.

Development of Generic Models of Intelligent Learning Sensors.
Fernando Figueroa, Tulane University.

Wavelet Based Representation for Matching Problems in Vision.
Andrew Laine, University of Florida.

Machine Vision for Composites Manufacturing.
T. Folsom, QUEST Integrated Inc, Kent WA 98032.

Automatic Placement of Vision Sensors.
C. Cowan, Advanced Automation Technology, Stanford Research Institute.

Multi-Sensor Data Fusion for Estimating 3-Dimensional Object Pose Under Time Evolving Conditions.
R.Luo, North Carolina State University-Raleigh.

Laser Phase Array Generation of Ultrasound for On-Line Weld Quality Control.
Charles Ume, Georgia Institute of Technology.

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George Chryssolouris, MIT.

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Nino Masnari, North Carolina State University-Raleigh.

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B. Peterson, University of Alabama.

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C. Thompson, MIT.

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G. Was, University of Michigan.

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M. Flemings, MIT.

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N. Thadhani, New Mexico Institute of Mining and Technology.

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The Mechanics of Powder Consolidation for Composite Materials.
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Synthesis of Pseudo-Fuzzy Logic Controls for Chemical Processes.
Thomas Co, Michigan Technological University.

Conceptual Framework for Linear and Nonlinear Control.
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Nonlinear Adaptive Control Theory Applied for Chemical Process Control.
Erik Ydstie, University of Massachusetts-Amherst.

Intelligent Monitoring and Control of Chemical Processes using Wavelet and FJ Transforms.
Rodolphe Motard, Washington University-St.Louis.

Geometric Methods for Nonlinear Multivariable Process Control.
Costas Kravaris, University of Michigan.

Expert System for Process Control.
Lyle Ungar, University of Pennsylania.

Robust Controller Design for Systems with Constraints.
Manfred Morari, California Institute of Technology.

Spray Forming for Metal Matrix Composites.
Jung-Hoon Chun, MIT.

Processing of Metal Matrix and Ceramic Matrix Composites.
Hari Dharan, University of California-Berkeley.

Investigation of the Thermomechanical Behavior of Compression Molded Fiber-Reinforced Composites Parts.
Tim Oswald, University of Wisconsin-Madison.

Shape Control of the Calendering Process.
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Filament Winding of Thermoplastic Composites.
George Springer, Stanford University.

Numerical Simulation of Solidification and Shrinkage Prediction of Cast Irons.
Fred Bradley, University of Wisconsin-Madison.

Process Sequence Design in Metal Forming.
University of California-Berkeley.

An Analysis of Grinding of Superalloys for Off-Line Process Optimization.
G. Sathyanarayanan, Lehigh University.

Closed-Loop Control of Sheet Metal Forming.
David Hardt, MIT.

Forming Complex-Shaped Advanced Composite Parts.
Timothy Gutowski, MIT.

Modeling of Continuous Casting of Steel.
Jonathan Dantzig, University of Illinois-Urbana.

Manufacturing Underground Space.
Carl Peterson, MIT.

Constitutive Modeling of Mechanical Response of Materials in Semiconductor Devices with Emphasis on Interface Behavior.
Chandrakant Desai, University of Arizona.

Stability Analysis of Interfaces in Coextrusion Flows.
Antonios Liakopoulos, Lehigh University.

Net-Shape Die Casting of Complex Parts.
Kuo Wang, Cornell University.

Picoliter Droplet Dispensing for Electronics Manufacturing.
David Wallace, MicroFab Technologies, Inc, Plano TX 75074.

Computer Integrated Analysis of Deformation Processing.
David Parks, MIT.

Mold Filling and Curing in Resin Transfer Molding and Structural Reaction Injection Molding: Micro and Macro Analyses.
James Lee, Ohio State University.

Thermal Aspects of Grinding.
Adrienne Levine, University of California-Los Angeles.

Solid-Liquid Interface Morphology During Welding.
Lucien Brush, University of Washington.

Concurrent Preform and Process Design for Formed Products.
Abhijit Chandra, University of Arizona.

Solid Freeform Fabrication of Ceramics.
Joseph Beaman, University of Texas-Austin.

Modeling of Hot Isostatic Pressing Process.
Gustavo Weber, Carnegie Mellon University.

Planar Flow Melt Spinning of Molten Metals:Fluid Mechanics, Heat Transfer and Solidification.
Paul Steen, Cornell University.

Advanced Polymeric Materials:Characteristics of Mechanical and Thermal Properties of Advanced Composite Pultrusions.
James Vaughan, University of Mississippi.

Laser Beam Splitting and Materials Processing.
Elijah Kannatey-Asibu, University of Michigan.

Predicting Engineering Properties in Injection Molded Parts by Neural Network Computation.
Byung Kim, University of Massachusetts-Amherst.

Geometric of Dextrous Manipulation.
Bhubaneswar Mishra, New York University.

Intelligent Dynamic Control of Automated Guided Vehicles.
Leslie Interrante, University of Alabama-Huntsville.

Towards Control of Time Varying Systems:Qualitative and Quantitative Modeling.
Mieczyslaw Kokar, Northeastern University.

Position/Force Control of Robot Manipulators in the Presence of Uncertainity.
Darren Dawson, Clemson University.

Automated Design of Aerospace Assemblies.
W. Fujimoto, Advanced Structural Technology, Inc, University City MO 63130.

Cyclides in Solid Modeling.
D. Dutta, University of Michigan.

Automated Fixture Design.
Paul Cohen, Pennsylvania State University.

Production Capacity and Layout Analysis of a Textile Industry.
J. Ventura, Pennsylvania State University.

Human Interface Design for Complex Systems.
R. Eberts, Purdue University.

Knowledge Representation for Functional Design of Mechanical Assemblies.
J. Wolter, Texas A&M.

Automated Assembly Planning for 3-Dimensional Mechanical Products.
T. Chang, Purdue University.

A Rule-Based Simulation Algorithm for the Dynamics of Part Orienting and Position Operations.
B. Gilmore, Pennsylvania State University.

Development of Science Base for Planning and Scheduling.
M. Caramanis, Boston University.

Modeling, Monitoring and Control of Abrasive Flow Machining.
Kamlakar Rajurkar, University of Nebraska-Lincoln.

Automated Surface Finishing of Molds and Dies.
Michael Philpott, University of Illinois-Urbana.

Intelligent Machining, Monitoring and Diagnostic System for Quality Assurance.
Anthony Okafor, University of Missouri-Rolla.

Machine Tool Research.
George Tlusty, University of Florida.

Systems Research Center.
John Baras, University of Maryland.

Center for Net Shape Manufacturing.
Taylan Altan, Ohio State University.

Engineering Research Center for Intelligent Manufacturing Systems.
James Solberg, Purdue University.

Sensing and Control of Selected Manufacturing Processes.
Kim Stelson, University of Minnesota.

Neural Network Error Compensation of Machine Tools and Coordinate Measuring Machines.
John Ziegert, University of Florida.

Three Dimensional Printing;Rapid Tooling and Prototype from a CAD Model.
Emanuel Sachs, MIT.

Sampling Techniques for Coordinate Measuring Machines.
Robert Hocken, University of North Carolina-Charlotte.

Discrete Surface Representations for Simulation, Verification and Generation of NC Programs.
R. Drysdale, Dartmouth College.

SECTION II:

- Transcript of Keynote Address by Thomas J. Murrin, Dean, School of Business Administration, Duquesne University
- Transcript of Industry Panel Review

The Federal Conference on Intelligent Processing Equipment (IPE) featured a keynote luncheon address devlivered by Thomas J. Murrin, Dean of Duquesne University's A.J. Palumbo School of Business Administration. Prior to that, Dean Murrin served for 18 months as Deputy Secretary of the U.S. Department of Commerce, as nominated by President George Bush and confirmed by the U.S. Senate. The following is an edited transcript of his remarks.

I am really delighted to be here. I'm particularly delighted to have Bob Schwinghamer introduce me because, as I mentioned to him just before, the NASA Advisory Group got to visit his Center (NASA's Marshall Space Flight Center) several months ago, and as you know visiting NASA is always very impressive and so forth, but this was the first time, frankly, and I put this in a letter to Admiral Dick Truly, the first time I was really impressed by a key government person talking very, very knowledgeably and practically about quality and productivity improvement endeavors.

I had the opportunity to sit and listen to much of the IPE panel discussion this morning and found that very, very, valuable, and I hope it is very valuable for all of you, and I hope this conference in general proves to be very valuable. One simple test I've always applied over the years is that if you take the time and effort to attend something like this and the cost of it in different kinds of resources on the organization you represent, one really ought to assume the responsibility of taking something away that proves later to be of real value. And given the exposure to the humongous array of know-how that you have here in this conference, it's hard to visualize that won't happen. So if you let me "goose" you at all in any way as a colleague in this field, take on the task of selecting something of real potential value to you and your organization and do something about getting it implemented in the future.

The session this morning that I sat in on had to do with technology transfer, as many of you know. I was more than a little bit involved in the beginning of the FCCSET (Federal Coordinating Council for Science, Engineering and Technology) as some people irrevelantly say. Allan Bromley (Assistant to the President for Science and Technology) is doing a super job in my view in fixing FCCSET and getting a lot of new initiatives going, not only behind the scenes but in front of those very difficult and demanding lights in D.C., taking a leadership role in helping different and usually disparate federal agencies to communicate and cooperate together and in turn do that much more effectively with industry and with academia and labor. That is no small task. I might observe just from listening to lots of pretty important and influential and, I think, knowledgeable and well- intentioned people in D.C. in the last several months that there is a tremendous range of viewpoints on whether or not what you are about in this technology transfer effort can succeed. There are some very knowledgeable people who have the conviction that the know-how in the labs by its very nature and because of the way it was developed really doesn't lend itself in a practical sense to being transferred elsewhere. I don't think they are being critical or negative, they are just realistically saying that it's time to face up to the reality of reducing the costliness and size of those labs as the economy seems to be dictating. Others assert that there is tremendously valuable know-how there if we could just move it more expeditiously and effectively out of the labs and into industry. And so they talk about CRADAs and reducing the review time from 18 months to 12 months to six months and hopefully to a few weeks sometime. And then there is a third school of thought that can pick a few real live success stories and hold them out as potential prototypes of what could be happening very generally.

The reason that I go into all this is to say that somebody is going to be making decisions soon about the size of these laboratories. And what happens to this national asset, and my impression is that you represent, certainly in the aggregate, here as much insight into that process and its potential as probably any group in the country. So if you have any mechanism to pull your thoughts together, and communicate them, I know they would be welcomed in Allan Bromley's office and I would also suggest that you would direct them into the private sector Council on Competitiveness, which is in the middle, literally, of an effort aimed to trying to figure this out at the same time.

I really know very little about, particularly the technology aspects of, what you are doing here. I used to be fairly up to speed a few years ago when I was in kind of the real world working for a living, but some time in government and now in academia tends to remove one from that. Let me share with you a statistic that I think is notable. I don't know whether it is good news or bad news concerning our American business schools, which is where I now am. In our great country we have 280 accredited business schools. They obviously have 280 business schools Deans. Somebody asked recently, and only in the last few months, apparently for the first time, of these 280 business school Deans, how many of those individuals have had any significant experience in business? It turns out the answer is 27.

If you are not familiar with academia, it's quite different than industry. Think about the implications of what I just said. And think about why it is, for example, that no American college or university at this time has a curriculum that contains adequate training and quality or productivity improvement. None. Some are starting. We and others are very enthused about this, but how could it be that that area of expertise which virtually everybody would agree is very important for the training of business leaders has until now been absolutely neglected. Bob Kaplan at Harvard recently ran a study of several hundred published journals -- refereed is the operative term here, that means it goes through some very demanding academic wickets -- published in the last two years in the leading six journals, where you would expect to find refereed articles relating to quality and productivity. Hundreds were published in total. How many would you guess related in any significant way to quality and productivity improvement. Again, we could take a survey. It turns out that in this instance, Bob judges the answer to be zero. Zero. So we have lots of opportunities in different areas.

Let me comment on a few things that I hope are of interest. I have been in different kinds of areas to see different things. I am very much unlike the attitude that I am told is represented by something that Dr. Henry Kissinger is reported to have said recently at a conference in D.C. Henry supposedly said "I am not as smart as God is, but I am as smart as God was at my age." I'm much more comfortable with what I understand to be a Chinese proverb that asserts, "a fool on a mountaintop sometimes sees more than a wise man in the valley." Some of these experiences have been kind of metaphorical mountaintops.

Someone, and someone smarter than I frankly, has suggested there are four key factors that will mostly determine the outcome of the international industrial competitions that many of you have been talking about and much of this conference has been dedicated to, at least implicitly, in the last couple of days. I find that these four factors are really crucial, I think one of them particularly so. Like so many other things, when you hear them, there are no really great surprises. But it is suggested that the four comprise the following: national will, capital, technology, and education. In my own view the one that stands out as the most important of the four is that matter of national will. I think a case can be made that the other three are all crucially important. And there are lots of other factors as you know also, besides capital, technology, and education.

National will I think simply relates to the coming together of leaders, in this instance in a nation -- it really applies to any community, I think it applies to most any organization -- coming to some sort of a consensus on what's really important and then working out a game plan to try to achieve the important goals that they put as their highest priority. I would assert, and particularly after two years in D.C., that we have not in any significant way established industrial preeminence or global competitiveness or even in a meaningful way standard of living and purchasing power and opportunities for our children. We have not made that our national will. Now we have done lots of things that relate to that, but we have been preoccupied in many respects, understandably so, with other goals like maintaining peace and political stability around the world since World War II. But other nations, and probably most notably Japan, have had a national will relating to competitiveness and industrial preeminence that I think has been really, for a long time, very clearly stated in what their Prime Minister says and what their diet does and the way they cooperate and team together and come to consensus and develop game plans among their leaders in government, business, academia and labor. There's a meeting in downtown Tokyo every Monday morning for about 40 years now where they discuss at the highest levels the various sorts of things that we have been talking about this morning. It's aculturated with them. Now I'll come back to that because I think something really very important and really encouraging is happening in our country.

Up until now, without trying to be pessimistic or discouraging, what I've tried to reflect in my comments to important groups like this and other occasions, is that I have been really worried, really concerned whether we have the capability to come to national will in this regard. Now we can talk about capital, we've got lots of problems there also as to its availability, as to its costs, and maybe most importantly, as to its so-called patience. We seem to live from quarter to quarter and be preoccupied with our earnings-per-share statistics and industry. The Japanese and the Germans have a very different report card than we. They are much more interested in long term global market share gains than in quarter-to-quarter earnings-per-share performance. I think that gives them some tremendous advantages, frankly.

In leading technology, in world class education, everybody is kind of a expert. Now I don't think this is new to anybody, and I may exaggerate the reality a little bit, but I think some events of just the last several weeks are in the aggregate a milestone in our changing attitude regarding national will and the importance of the economy and competitiveness and technology transfer, if you will. Probably the single most notable event happened literally under our noses in little old Pittsburgh, Pennsylvania, when over a several-week period, Dick Thornburg's political position and his senatorial competition with Harris Wilford went from a 47% lead to a 40-60 loss. I think that was a microcosm of what is going to happen across our country in the presidential election. I don't mean to predict that anyone party will suffer a particular loss, but what I do mean to assert is suddenly our citizenry have become so concerned about what they now realize is limited and declining real purchasing power, less opportunities for their children than they had relative to their parents, and some uncomfortable competitive developments by other countries, that they are saying to whoever is the incumbent in Washington, D.C. of whatever political persuasion and whether in the White House or in the Congress, "A plague on your house!" I think this is very real and very important and hopefully very encouraging.

Now just so this doesn't sound like one person's rambling, let me share with you something that some of you may already know about, but I think all of should, and at least indirectly, all of you will in the coming weeks and months. Some of you have said nice things about the private sector Council on Competitiveness and I happen to be on their executive committee. I think those nice words are well founded, frankly. A little bit of background very quickly on that council. In 1983, President Reagan, through Malcolm Baldrige who was then the Secretary of Commerce, organized the Presidential Commission on Industrial Competitiveness, about 30 people from government, industry, labor and academia. I was privileged to be one of those. They worked very hard for about 18 months, had dozens and dozens of meetings, developed some very significant insights into what was then happening to our economy and what we are to do about it, and wrote a report that was of potentially great value. I was there at the press conference the last day, the TV cameras rolled, Secretary Baldrige spoke for part of the time, the reports were handed out, a little bit of Q&A took place, it started at 10:00 and ended at 11:00, and at 11:00 it's always almost as if that process completely ended and everybody that was involved fell off the globe. The staff was disbanded, the commission went its various ways, by then the election outcome had been determined, so it wasn't necessary for anybody to do some of the very difficult things that that commission suggested had to be done. But to their credit, and particularly due to John Young of Hewlett Packard who chaired the commission, this follow-on group, now called the Council on Competitiveness, was formed with many of the same people. It's been laboring ever since, doing some good things as some of you graciously referred to today, but without very much impact, frankly. And now all of a sudden people are asking what should we do and what is our problem and so forth. And these many years of hard work are perhaps going to pay off.

One of things that the Council did several months ago, and I nothing to do with this so I can be enthusiastic about somebody else's idea, is they had the vision to somehow anticipate the attitude of the citizenry in regard to the coming presidential election. They commissioned a political survey across the United States involving two of our countries leading political analytical groups: one normally working with the Democrats, and one normally working with the Republicans. Another stroke of genius. And, happily, they worked pretty well together; they are real professionals. They have now finished the survey and I am going to read to you just a few brief bullets of what comes out of the survey. The very significant thing is that what happens next, and this is really starting to happen, is that every presidential aspirant running in any state at any place in this country between now and next November, will be personally briefed in detail with the horns, lights, bells, charts, whistles, the whole nine yards, of the survey. One of the first zingers is a pie-shaped chart that asks citizens across the whole country, "What percentage of you think our economy is in excellent shape?" And, literally, that got zero responses. "Good shape" got 10% of the respondence. Most of the people thought we were in poor to very poor shape. Let me just read a few of these highlights. And I am quoting. "There is broad concern about the present recession and the long term future of the U.S. economy. Both pollsters, these are the people now I mentioned, believe that the condition of the economy will be the primary force that shapes the election campaigns. Most Americans feel a squeeze on their personal standard of living and feel it is impossible to save. They believe that they will not live as good a life as their parents and that their children will have an even harder time starting out in life. Americans fear that the worst is yet to come in terms of foreign competition."

Now let me add a couple of partenthical inputs here because I was fortunate to get, on two occasions, the briefings from these people. They volunteer two differences in this poll from earlier surveys taken in earlier recessions, because we have had problems like this, as you know, before. In earlier recessions, the negative responses almost always came primarily from the unemployed or the undereducated. In this survey the negative responses are found across the whole spectrum of respondents, including CEOs and presidents and chairpersons and professionals and what have you. In the earlier surveys virtually everybody agreed, including the folks out of work, that in a short time, things were going to get better, they had to get better. In this survey, virtually everybody expresses the view that they are going to get worse, and maybe much worse, before they get better. Let me pick up a couple of more. A majority believe that the U.S. ability to compete has gotten worse and see us behind Japan, but still ahead of Germany. And they add, interestingly, people also believe that Japan got ahead using unfair trade practices. The government tops the list of who to blame for economic problems. Now that's different. In the earlier surveys, folks who got the most criticism were business leaders. They are now in third place in this survey: congress first, administration second, business leaders third. To resolve American's economic competitiveness problems, most people feel that the Federal government must take a more direct activist role in working to be a part of the solution. The majority want a President who will work with business to improve the economy. And then the final one that I will mention, people are also bothered by the fact that young Americans are no longer the best educated in the world.

Now let me read two paragraphs from the Council's comments here which I think relates very much to what you are about. Based on the poll, the Council has a great opportunity, and I think you have a great opportunity, to ensure that competitiveness issues are thoroughly debated in the 1992 elections. People do not always fully understand the importance some of the key elements, such as critical technologies of industries. But there is a receptivity to looking at the longer term, such as to a 21st century infrastructure. That's a key point and a key challenge for us. If you go out and talk about fiber or carbon, fibers and silicon, gallium arsenide, and silicon devices to the typical citizen on the street, they are not going to associate that with their own economic well being. So folks like you, like us, got to help really explain how that all ties together. In my experience, if you talk to the typical Japanese, they can explain to you how this all ties together, because they have been hearing this in their schooling, workplaces, and in their media. We have not been communicating that. The Council's challenge is to educate voters on the links that exist between technology, training, infrastructure, and savings and investment on the one hand, and long-term prosperity and a rising standard of living on the other. It is important to establish a good visible connection between competitiveness and the economy. It's in the poll, but implicitly. If we don't make it clear, people may not pick up the connection. That's a big, big, challenge.

Let me just comment briefly on capital. The matter of capital -- and that was really implicit in much of the panel discussion this morning, I think -- we've got a lot of technology, we are talking about transferring it, but as was pointed out a few times, if we don't have the financing to develop the facilities to do the commercialization, to do the marketing, we are not going to have much favorable impact. And what is, of course, particularly painful is to be in that process, run out of capital and then have some of our embryo businesses be taken over by people from other countries. A lot of that is happening, as I expect you know. Well, this relates in part to the view that a lot of people have, that American business leaders are, as it is critically put, shortsighted and adverse to risk taking. More nicely, and academically, stated, it has to do with time horizons.

Time Horizons is the name of a major study sponsored in large part by the same Council on Competitiveness lead by Dr. Michael Porter at Harvard, who I am sure you know about, and involving about a dozen of the nation's outstanding academics and other experts relating to the field of capital. The early indications of how the study is coming out are now available and though Michael Porter is obviously very anxious to protect his own interests, and Harvard's as to how this gets published in books and so forth and so on, I think I can share with you without compromising at all his situation, some of the key results that are coming, and this may prove to be a seminal piece.

My reaction to much of this, to be very honest, and I make Michael a little unhappy because I am very honest with him, is to say "Michael, you couldn't have trudged around the world for the last 20 to 30 years and not known that the time horizon of Americans is different from the Japanese and the Germans." But what almost always happened is if a business person said that, most of the American listeners discredit it, frankly. They did not accept that as credible. When an academic says it, particularly if it could be supported by a lot of data and books and graphs and all that jazz, then it takes on sort of godliness. It's dogma. Well, this process is underway. They are confirming that there is a difference and it's a very big difference. They are very imaginatively, I think, explaining some of the mechanisms as to why it is different in a way that is really very helpful and both of those aspects of the study, I think, you are going to be tremendously impressed by and interested in.

The third part, though, is the very difficult part and I don't know that they're even optimistic yet about it -- that's the "what do we do about it?" Because it turns out our system is so fundamentally different than the Japanese or the Germans that it's hard to think about how we change this, at least quickly. Now let me just read, not from Michael's writings but from one of these supporting documents, a little bit about this to give you a flavor for it. It says, "A paper on time horizons of American firms, new evidence from a survey of CEOs," from an MIT professor and a Harvard professor, and the Harvard chap is also associated significantly with the World Bank. So this paper describes the results of a sample survey of chief executive officers at a thousand of the largest firms in the United States. More than 200 of these firms answered our questionnaire about the determinance of corporate time horizons. Let me just quickly hit about four of the key insights that come out of this effort. First, the hurdle rates most U.S. firms use in their capital budgeting procedures are higher than standard cost of capital analyses would suggest. The average discount rate applied to constant dollar cash flows was 12.2%. It's distinctly higher than the average rates of return earned by equity holders and much higher than the return on debt during the last half century. These findings suggest that managers may be turning away projects that would in fact be profitable if viewed from the shareholders' perspective. Second, U.S. managers believe their firms have systematically shorter time horizons than do their major competitors in Europe, and especially in Asia. This result does not seem to reflect some form of managerial paranoia. And let me repeat that, as a former management guide. This result does not seem to reflect some form of managerial paranoia. What they say, actually, and it is not written here, is if you took the American executives and put them in the setting of the Japanese or German environments, they would act with long term vision and grace risk-taking perpetuity. If you took the Japanese and moved them into our quarter-by-quarter scorekeeping system, they would act very much like we do. The U.S. CEOs typically believe that their own firms have a larger horizon than their typical domestic competitors. That's interesting. Our limited surveys of managers in Japan, Germany, and the United Kingdom, show that foreign CEOs agree that their firms take a longer view than their U.S. competitors. And when you look at the data and listen to the information overall, it's a fundamental difference, it's not just cosmetic, it's a fundamental difference as to how you manage a business enterprise and how you invest your resources, particularly including money. Third, most managers think that the U.S. equity market undervalues their long-term investments. The evidence on whether such valuation errors translate into reduced investment is less clear. Saying this another way, if you want your stock price to plummet precipitously, call a meeting of U.S. investment analysts and explain to them that you are making a major new initiative to invest a lot of time and money into some, you hope, promising R&D effort. I mean this has happened countless times. They will literally leave the room to make phone calls, not to put in buy orders, to put in sell orders. So that's the kind of environment we are operating in. Fourth, CEOs believe that government policy could effect, or can effect, corporate planning horizons. Several policy reforms, including a cut in corporate tax rates, making an R&D tax credit permanent, a corporate tax reduction for dividend payments, and a credible commitment to a stable tax policy for the next decade received enthusiastic managerial support. These policies were viewed as more attractive than restoration of the investment tax credit for equipment, a capital gains tax cut, various anti-takeover changes and corporate control regulations, or a tax on short term trading.

Let me just mention that in the software area, where I think many of us have been convinced that's one technology segment where the United States still I think there are some credible clues that that view is not well founded anymore. For example, at least one of our companies has studied in great detail the reliability of new software coming out of American organizations versus the reliability of new software coming out of Japanese organizations. And it is quite clear that they have now surpassed us in regard to quality and reliability. So it isn't the perfect measure of merit, the software engineering institute performance rating which runs from 1 to 5 now rates quite a few Japanese companies 4 and 5 and American companies typically 1 and 2, with 5 being outstanding and 1 being very poor. The reason for this, principally, is a very simple reason, like so many things the Japanese do. In what they call a new software package is found about 65 to 70% of reused, proven modular software. For us, we reuse about 15%. We are still like John Wayne. Shooting them up. Creating, innovating, changing -- wonderful, except it's hurting us competitively. They are very cleverly proving out their software lines, modularizing it into functional, sort of generic groupings and then forcing their organization to reuse that software. It's not a trivial difference, it's a very importance difference.

And then I just came a across a report that I will read. I don't even understand this, but I'm sure many of you do. But it sounds not like good news. The MITI-formed organization called IPA (Info Processing Association), not IPE, is consigning portions of its software R&D to the Standford Research Institute. And I will read the words in this report: "To create model software that can modify its structure in response to changes in the surrounding hardware environment or application." The amount of money committed is $23 million. Not a trivial amount. I mentioned this to one of the CMU (Carnegie Mellon University) professors the other day, and he said our "this-and-that" is going to be the response to that. So I asked how long have we been working on our "this-and-that" solution? He said, "well, only about 16 years or something." And all of this in turn relates, as I hope all of you know, to the intelligent manufacturing system proposal of the Japanese. I sort of lost track of that, but this was to be a billion dollar, ten-year program, pulling together the U.S., Japan and Europe, and helping all of humanity. I think it has some prospects for good if we manage it well, and I think we ought to look open mindly at that.

Thank you very much for your attention.

IPE PANEL DISCUSSION

Thursday, December 5, 1991

Industrial Panel:

Ric Davis, President, Martin Marietta Manned Space Systems
Robert Becker, President, In Tolerance, Division: Norman Scott Company, Inc.
Hadi Akeel, General Motors-Fanuc Robotics Corporation
Dr. Charles Hamermesh, Technical Director, SAMPE
Steven Scarborough, Manager Control Systems, Honeywell Sensor and System Division
Vern Solberg, Development Manager, SCI Corporation
Steven Babcock, Director, Advanced Manufacturing, Rocketdyne
Bruce Brock, V.P. of Corporate Quality, Manufacturing and Quality, Honeywell
Dick Lopatka, Assistant Director of Research, United Technology Research Center
Michael Cronin, Chairman of the Board, Automatix Inc.

Introduction and welcome by:

Robert Schwinghamer: Good morning ladies and gentlemen. We will begin today the third and final session, the Intelligent Processing Equipment Symposium. I might mention that with regard to the original program Vern Solberg has taken Steven Katz's place, Dr. Hadi Akeel has taken John Bolinger's place and Mark Bursick called in yesterday and he had a personal emergency, so we won't see him today.

I thought it may be appropriate to—I guess we are preaching to the choir almost here, but Leo mentioned that somebody didn't know about the FCCSET. Maybe a little on the genesis on this symposium. The Federal Coordinating Council for Science Engineering and Technology has a committee on Industry and Technology and they put out an agency invitational memo in May of this year outlining an advanced manufacturing plan initiative. The CIT Steering Group then ended up under J.R. Thompson who was then NASA Deputy Administrator and as a result of that, we formed an inter-agency task team. The CIT basically assess the four critical manufacturing process technologies that came out of the National Critical Technologies Panel and that report, I believe, came out in March of this year. They singled out—it was not only addressing manufacturing, but under the category of manufacturing-they singled out Flexible Computer Integration as a crucial technology. Intelligent Processing Equipment is one, Micro and Nano Fabrication is another and then finally, Manufacturing Systems Management Technologies. It was then decided that we would host a national symposium on Intelligent Processing Equipment. I guess we followed in a sense the hippocratic oath, primum non nocere, "first do no harm" (humor) so maybe we are a little bit more timid than we should of been, but the idea was not to mess things up. We then decided that three objectives would be in order to try to assist the Intelligent Processing Equipment status across the government agencies which ought to give the agencies themselves some indication of what's going on in the other agencies. As a member of NASA, you know its a real struggle to know what the Air Force is doing, etc. etc. etc., and we probably don't do enough of that in the Federal Agencies. And then we planned for the agencies to present their data in the symposium, and we have had two days of that now where the agencies did present their Intelligent Processing Equipment information. Then on the third day, which is where we are today, we convene the high level industrial panel. We have all these heavy hitters over here to my left and we are going to try to assist the government activity and make some recommendations. So that was generally then the objective. So I think without further ado we will turn this over to Ric Davis who was nominated as the moderator by the industrial panelists.

Ric Davis: Thank you Bob. Let me try to give you an idea of the format we are going to use. First I would like each of the panelists to introduce themselves and maybe characterize their firm for us a little bit in terms of the size, and maybe what its primary capabilities are. Then I would like each one of the panelists to make some observations relative to the thinking they have done and the sessions they have attended in the last couple of days, that they believe will shape their answers to the primary questions we have. [Are the questions on the vu-graph machine? If they are, why don't you just flash them up.] Try to stay away from answering the questions in the process, but just present observations that you think shaped your answer. Then we will try to address the questions.

I would like to address both questions 1 & 2 at the same time. I found it difficult to stay with question one without finding out that the answer is applicable to question 2 also. But also I did find out in answering 1 and 2, the answers to question number 3 came to me. So first we would like to go through the panelists getting their reaction to questions 1 and 2, and then go back through again with question 3. In doing that I would ask them to try to be brief, but do take the time necessary to get your point across—don't feel rushed. If a previous speaker has a made a point that you think is very important, go ahead and support it, but don't dwell on it unless you have something new to add, some new aspect that you think is important.

After the panel session is finished, we will then take questions from the audience. When we do, we would like the person asking the question to stand and identify himself and his affiliation. I will try to repeat the question, so keep it simple for me please. We are taping this session and there are no mikes in the audience and we do want to get the questions on the tape. If you just want to make some observation, I would suggest you come to the podium and use the mike because I don't feel I could capture your observations if I try to repeat it. We will try to take a break about 10:00. So with that, why don't we ask first each of the panelists to introduce themselves and characterize their company.

I am **Ric Davis**, President of Martin Marietta Manned Space Systems down in New Orleans. It is about a 3200-man operation. We run the Michoud Assembly Facility for NASA. It's a Go-Co (government-owned, contractor-operated) facility. Our primary product is the External Tank for the space shuttle. In addition, we have some other research tasks, but the ET is our primary product. So with that I will pass it to Bob.

I am **Robert Becker**. I am president and owner of a rather small concern, that is, compared to Martin Marietta; we're a contract manufacturing company called: In Tolerance. We have 30 people in Cedar Rapids, Iowa; manufacturing precision machine components for industry, government, and medical devices, being FDA Registered and Certified to MIL-I-45208. We have been in business for approximately 45 years. I got involved with IPE through a technology transfer. We are involved with the RAMP (Rapid Acquisition of Manufactured Parts) program that you have heard about in yesterday's presentation. DoD and FEMA have sponsored this to improve the productivity, and to speed delivery - from purchase orders on through to delivered parts. I'm happy I got involved and my comments will specifically be geared toward small business owners and what can be done to that extent.

I am **Hadi Akeel**, Vice President and Chief Engineer of GMFanuc Robotics Corporation. We are an American company, a 50-50 joint venture between General Motors and Fanuc Limited of Japan. Our company is proud of being an American citizen, and I hope my comments in here will not be considered in any way biased by our mixed ownership. Our company is the largest robotics company in the U.S., with sales volume over $250 million for 1991. We have subsidiaries in six countries in Europe as well as having markets in Australia and the Middle East. We are developers and manufacturers of robots as well as importers of Japanese robots. What I'll present in hers is possible a feel for the robotics industry in the U.S. as well as for the general market - well that's if there really is such a thing as robotics industry in the U.S., we may represent about 80% of the industry in terms of the manufacturing capability as well as the application. My background is mechanical engineering and I have a doctoral degree from the university of California at Berkeley. I have been in the robotics business since 1974, originally with General Motors and then GMFanuc Robotics.

"Government sponsored research will effectively enhance the countries competitiveness only when general manufacturing industries can decide the direction and objectives of the research".

Good morning, I am **Vern Solberg**. I am with SCI Systems. SCI Systems is a 30-year old company. They originally had operations in Huntsville, Alabama. Since the growth in the industry they have expanded, however, to about 18 facilities throughout the world. Most of those facilities are in the U.S. We have two facilities in Asia, two in Europe and the remaining in North America. The company is just over a billion-dollar-a-year revenue company. We supply service, we don't have products of our own with our own label. We provide services, in most cases to other electronic companies. They contract much of the assembly and test out to our facilities in different regions in the country. We do have a military--or what we call a government--division, and that's where the company started in Huntsville and they continued to make avionics equipment and they have a good solid business base—its about 200 million dollars a year. Total employees of the company worldwide is about 11,000. The benefit to the customer base is they work on a rather low overhead base and they keep competitive in a world market that has become increasingly aware of keeping cost down to get the product out as quickly as possible.

Good morning, my name is **Steve Babcock**. I am Director of Advanced Manufacturing at Rocketdyne Division of Rockwell International. Rocketdyne, in case some of you don't know, is a major builder of rocket engines and we also build power systems for both space and land use. We have been known over the years as a premier rocket engine builder, going back to the early days of the Jupiter and Thor (missions) up to the present time where currently about 40% of our business is building the Space Shuttle Main Engine. We're sort of in a transition period at Rocketdyne, going from an engineering-oriented company trying to transition into a process and premier manufacturing organization, and as a result we are involved in tech transfer and also in the use of intelligent processing equipment. We have been involved for about 5 years now, working at the Marshall Space Flight Center, dealing with technology transfer directly from the Center laboratories into our manufacturing shop, and I will describe some of that a little later. My personal background involves both the aerospace business that I am in now, as well as the automotive area. I spent 19 years at General Motors. Looking back at some of the ways we dealt with technology transfer, we were actually transferring technology from the aerospace side in those days into automotive and today we look for transferring technology the other way in addition trying to find technology wherever it may reside.

Good morning, my name is **Bruce Brock**. I am a Honeywell corporate Vice President for manufacturing, quality materials, and environmental health and safety. Honeywell, as Steve said, is a global controls company. We are about a $6 billion in sales and about 58,000 employees, with close to 40-50% international sales. We are a high technology company, and of course many of our products are involved with intelligent processing equipment. Our markets are residential controls, building controls, industrial controls, (continuous processing & batch), and one of the world's largest commercial avionics supplier. We also are in military avionics and space. We are a 106-year old company and are very interested in maintaining our global competitive position; therefore, the deployment of technology is important. While we have our own research centers, and Steve is from one of those, we are very interested in trying to improve the process of deploying technology.

Good morning, my name is **Dick Lopatka**. I am Assistant Director of Research at the United Technologies Research Center. My principle area of responsibility is manufacturing technology and manufacturing systems. Most of you would know United Technologies by its subdivisions. United Technologies is a $22 billion company made up of an aerospace side of the business and a commercial/industrial side of the business. In the aerospace side of the business we have Pratt-Whitney in the U.S. and in Canada, making commercial and military engines and space products, including refurbishing boosters, solid propellant rockets. We have Sikorsky Aircraft that makes helicopter, Norton and Hamilton Standard that makes control and electronics equipment for military application. About half of our sales is in the aerospace side. The other half of our business is commercial/industrial, including Otis elevators, Carrier air conditioning and an automotive parts business. We are a large parts supplier to Ford Motor Company, for example. United Technologies has some strategies that you would be interested in. One is that we are a company now with over half our sales internationally. So we are working very hard to understand how we can compete in a world economy. This involves not only developing our products and manufacturing our products worldwide, but doing our research and development in a worldwide setting. So we are in the process of strategically sorting out what we as a corporation will be able to do domestically in R&D and what we will have to do internationally.

Secondly, we are in a major effort to move our technology from the aerospace side to the commercial side. So we are very interested in those strategies that let us take advantage of high technologies and get them to be used more in the commercial/industrial products of our company. Our third strategic area is to build up our area of manufacturing.

I have been very interested and please to see the presentation the last few days. United Technologies has been somewhat interactive with many of these operations. We have worked with NSF, NIST, DOD, DOE. Because of our business diversity, we manage to touch a fair amount of the agencies that have been talking to us and presenting their activities. Our corporation is very interested in what we can do in terms of working with the agencies that presented in the last days.

Ric Davis (moderator): Now as I remind you the format, I would like each of the panelists to give you some observations of his own personal view that he thinks shape his answers to those questions (1 & 2). Bob Schwinghamer has asked us to be very candid, very open and not be afraid of hurting his feelings, and somehow I have a feeling this panel is not going to shy away from that challenge. Let me kick it off if you will.

Ric Davis: First I think I'd like to try to paint a picture for you about where my view comes from. Most of my work in the last 15 years or so has been with NASA. I have had some exposure to the MANTECH program through my associations with colleagues in Denver.

We are very active in the NASA Technology Transfer Program; as a matter of fact, NASA put us on contract (as a trial case with our last production contract) to actually go and get involved in tech transfer. They gave us a sum of money to directly fund the effort. We actively promote transfer of whatever technology we have directly to the private sector and in the process, once we transfer it, to try to get some royalties in order to replenish the fund that we got on the original contract. We are very flexible with this. We don't always do that - - there was a single person corporation formed to get a product out in the lunch box area; obviously it was inappropriate for us to ask her for royalties on such an item. It is an extremely flexible program. NASA has been very willing to accommodate different formats with the primary purpose of getting that technology out into industry.

Unfortunately, I was not here to hear the comments on Tuesday. I did sit through the session Wednesday, and Bob, I think the idea of getting the agencywide view is invaluable, certainly to me in trying to participate in this program. I think that was a fabulous thing to do. So let me give you comments as a result of that exposure. What I found was a bewildering amount of technology R&D in process in almost every single national agency. The scope of the R&D is just unbelievable. However, I did note that each one of the agencies has markedly different objectives for that work, ranging from trying to just accomplish some pure research, to those who are trying to really apply the development of this technology to meet the agencies' needs, to those that are mainly interested in transferring technology out to anyone who can use it. So the objectives ranged significantly among the agencies. Equally diverse were the means for accomplishing those objectives, and for making the knowledge available to the end user. We have all sought of ways of doing it, some that involve significant resource investment by the user, some that involve a lot less. Large data banks are being developed and usually independently among the agencies. A significant amount of data is there, information is there, and methods of getting it to the end users really did vary significantly.

The end users targeted varied dramatically also, all the way from academia, to large companies that are going to apply it for the agency's needs, to just getting to the small business companies. I was quite impressed in one session by the SDI effort to bypass the major primes (like my company) and get directly into the small industry. I am looking forward to hear what Bob Becker has to say about that, because I really think, as much as anything, that is a key to really getting effective technology transfer. You've got to try to bust through those major primes and get down to the guys that really utilize it and make it happen. Also, I found out that generally the coordination across the agencies is minimal. And of course, the implications of that is that there is significant potential for duplication of efforts and costs. And again, I have no basis for saying there is a lot of duplication. There were significant examples of technology transfer. Practically everybody had their success stories that they could talk about, did talk about. However, there seemed to be little attention aimed at how do you measure the effectiveness of the program. You can talk about all the great things you did, but how do you measure how effective that was? Was that a reasonable return for the resources that were expended? Certainly the sums of money being expended are very significant. Some effort needs to be made to coordinate and improve the effectiveness between the agencies.

Another observation was certainly all of this activity was prompted by the congressionally mandated expenditure of funds to accomplish technology transfer. The agencies are reacting to that, reacting to it very effectively. Another observation I made is it is beginning to spawn its own support industry outside the government. I've seen evidences walking through the displays of newsletters that are being generated, access reports, consultants trying to get into the business of "How do you help the user to get to this wealth of data", a national society being formed, etc. That concludes my opening remarks. It's my view of what I think I saw and those things shape my answers to the questions that are coming up. With that, I will turn it over to Bob Becker.

Bob Becker: The general observation as I walked through some of the displays the past few days (and here I have brought a couple examples in one particular field) there are three different booths out there (on display) claiming to do database searches for an individual on papers, technical lectures, on anything that has been published, on going projects, or completed projects for the government, NASA, and the list goes on. That's three independent agencies that I found out there (on the display floor). An additional one if you count the National Machine Tool Society that claims to do such a search for you also. One is sponsored by a private company, funded by DoD, one is directly a NASA agency, and one is purely a private company that you pay for every database search. Getting just basic answers to what is going on, what database do you tap into, and once into a database one has a choice there between what group of people you want to ask the question to, let alone they have probably, of what I could understand, about 20 different databases they have to tap into.

In General we must become centralized, in where we find the information, where we deposit our information, apart from saying that DoD is sponsoring this one or NASA is sponsoring that. There should be an active agency that does nothing but funnel all information to one database for documentation on what we have already done so that we don't re-invent the wheel.

It is a fact that this country was founded by "revolution", and what we need now is an "evolution" within the machine tool industry (that is what I am familiar with) and processing improvement. There is a trend right now of TQM (Total Quality Management) in this country, as if all of a sudden America found it, and where many think Deming initiated it in Japan - but it actually was first invented here, but America rebuffed it. I refute the word TQM, management being the last word, and I believe it is a TQ/PI process (Total Quality Process Improvement) We must adopt a philosophy, as we have an active program back home in my facility, that being the "evolution", the process improvement within the shop and factory environment. The technology has to be applied to this the process improvement that you are trying to take place within in your environment it being chemistry, optics or manufacturing a machine part. The focus is wrong. We've got to start with the end product that we want to get, the process of how to get there, and then make improvements along the way. Technology and the development of Intelligent Processing Equipment has to be applied for that end goal and not on a shot-gun approach. I will talk in more detail later about what I believe can be done within government on helping small businesses.

Hadi Akeel: I've had the opportunity to sit on most of the IPE panels on Tuesday and Wednesday and also on some of the presentations of the Technology 2001 conference. I had a couple of days to tour through the displays. I share Mr. Davis' impression of being overwhelmed by the amount of technology that has been developed by the Government Labs within the Government facilities, and especially by the magnitude of funding that is devoted to this, whether within academia or within the support industries that actually get part of that development funding. The robotics industry is possibly a good example to use to see two things: (1) Where is the direction of research and development that U.S. funding is being directed to?, and (2) How effective the utilization of that technology has been within a representative industry like the robotics industry? That will be part of my presentation and my discussion later when we answer the last question of these three. But just to give you a little background, we all know that the U.S. robotics industry started with a bang in the 70's, fizzled in the 80's, and now is facing oblivion in the 90's. And that is despite a very massive effort that is very obvious in all of these presentations directed toward robotics. Robotics rally spans the three IPE elements of Robotics, Controls, and Sensors. So why, despite all of that effort, has the U.S. lost, or is about to lose, the robotics industry? Are we directing the research in the right direction? Are we establishing the right goals for the researchers? Do we know how to market that technology? I have seen dedicated and honest efforts for technology transfer by all the agencies and that is very encouraging, but the end result that we see from our side is that it has not really gone to help industry and it has not provided the kind of elements that would support a particular industry like this one.

If we look at the direction of research, we find that in the past two decades, the 70's and 80's, the Government effort has been directed towards research and development, advanced research and advanced development in very academic and much in abstract fashion, and millions and millions of dollars have been spent there. But is the robotics industry looking for the medicine of technology? The robotics industry may be sick, but the medicine is not necessarily the technology that the Government is developing. The industry seems to need just fresh air and exercise. It needs the markets in which it can be exercised, can be applied, and can go and actually find different ways of becoming more productive and cost effective for providing the benefits that the rest of society is looking for. How can the Government research funding provide that kind of environment is an issue that relates to question number 3.

These are generally my observations. I look at the input - - a lot of research, I look at output - - little goes to industry and I ask myself the question, "are we doing it right?". I hope this discussion and this panel will answer these questions.

Charles Hamermesh: As I said earlier, I know nothing about intelligent processing equipment and also must apologize for not having attended Tuesday or Wednesday, I did read the papers. Now you might ask, why is SAMPE, a society of members involved in materials and processing, interested in technology transfer? The answer is very clear. Our members and the companies that employ them have been primarily in the defense aerospace industry. The budget is going down, the Soviet military threat is disappearing, and very frankly, our people and their companies are asking where do we go from here? So the answer is, obviously, technology transfer. Now, therefore we've got to come to the question of what is technology transfer. I think there are several answers that have to be obtained here. Does what you're transferring do something better or something new or different? Can it be used for making the volume of product needed, and at that volume of product will you supply the quality of product required for the application? Finally, is it going to be cost effective within the realm that we are talking about? Now, once having said that, the other thing on technology transfer is something similar to what you learn in real estate—there's only three things important in real estate: location, location, and location. The same thing is true in technology transfer—you must have the right audience, the right place, and the right answer. If you don't have that, then you are wasting your time. One of the problems that may exist is that the government or the people attempting technology transfer haven't done the market research to address the proper audience at the proper place with the proper answer. You cannot wave your arms and say this is the greatest thing since sliced bread and therefore please take it, because it won't occur. I can give you an analogy that is over 40 years old. The first company that I ever worked for, the research director read an article which said that "bread is the almost perfect food because it contains every amino acid except lysine. Well this laboratory was in midtown New York and there was a slaughter house down the street. And from the blood of animals, one can extract lysine very well, and remember, this is in the late 40s. So our research director went ahead and developed a program which, in those days, ran up to $10 million in production of amino acids, particularly lysine. We were in production producing kilogram quantities a day, which is an amazing amount for the late 40s, when a rude fact came back to him which was that the millers did not give a hoot about bread being the perfect food and they couldn't care less about putting lysine in there. So we sold that wonderful operation at a nickel on the dollar. So are you in the right territory? And then I would like to end with one other rude question, and I apologize for this: are the government, the federal research laboratories and academia the right places for technology transfer to be handled?

Steve Scarborough: We have done a lot of talking as panelists. I have been here since Tuesday, late afternoon and have been attending the sessions from 4:00pm on Tuesday until now. I do appreciate all of the work the Government people went through to put this together.

I decided the first thing I am going to do is review what are we trying to do, and what is the problem? I went back and started doing some research on the information sent to me by NASA. It says "the ability of American businesses to compete in world markets is being hampered by the U. S. Government's failure to share with them promising technologies developed in federal laboratories."

This is according to a congressional report. So it seems to me that we are here, first of all, because U. S. industry is not able to compete very successfully on a worldwide basis. It occurred to me that, if the Pacific rim countries weren't so successful and if Europe, now combining in a united market, wasn't so successful, we probably wouldn't be here at all. We would keep going on like we have in the past inefficiently trying to transfer U. S. Government technology to industry. The United States is not short on technology. We have all the technology we need right now. So what is the problem?

In my opinion, the issue is that you can't sell technology per se, you can only sell solutions to problems. You can't drive technology down anybody's throat. I emphasize this is my job at Honeywell with my engineers because technologists love technology and they love to try and sell technology. Unless the technology is timely and meeting product needs for a company, it is not going to be accepted and you can't sell it. Later on, when we start answering the questions, I will offer to go through the Honeywell process of how we transfer technology as a typical model in industry, so you can understand the problems a Corporate Laboratory goes through to transfer technology to a division. It is the same kind of problem you people have.

Another roadblock to technology transfer that every Government agency has a primary charter. NASA's charter is to build space systems from Apollo to the Shuttle and now a Space Station, eventually to land on Mars. You can consider each organization; DOD makes weapons systems, EPA is environmental protection, SDI is defense against missiles, DARPA is five-to-ten year advance weapons systems, etc. It is appropriate that these charters do not develop products that are compatible with commercial needs and do not place technology transfer as a high priority.

Not one of the organizations have the charter to transfer technology to the commercial sector of United States industry. "Commercial sector" is the key.

Typically, the technology developed in the Government is very expensive, it is very far reaching in terms of being five and ten years ahead. Even in a high tech industry, like we are in at Honeywell, lots of the technology that we see coming out of the Government is five years ahead of when industry is even willing to look at it. So there is no one chartered in the U. S. Government to transfer technology to the Commercial Sector. There's no one like a MITI in Japan, or like ESPRIT in Europe, formed to work with industry and come up with the technology industry needs to be commercially competitive.

The Government is doing a great job in what they are doing, but your charter is not to come up with the kind of technology we need. Because of the pressure that is put on you by Government, by industry, by society, you have tried force transfer. In certain areas where we are losing, like Micro Electronics a consortium being formed (SemaTech). NCC has been formed to help the machine tool industry. Those are the right ideas, there should be an organization with the charter to do this job. If we don't do that, we are going to be wasting out time.

Vernon Solberg: SCI is in a little different posture. There are user technologies to help the next guy along. We use very sophisticated computer-aided design systems to develop IC's, print circuit boards, and chassis. What is shocking is that none of these systems seem to talk to each other.

None of the languages, none of the outputs are compatible with each other. So we have to take the data and manipulate it so it can fuse down the process. What we are looking for is a common language output, common format output, so that we can transfer data quickly and easily. A good example of that effort is with IPC. IPC is not a government sponsored or more funded operation. That's an industry operation, all volunteer. They have been working now for about three years to develop a common language format, and it is called IPC D350. It will speed up the entire transfer process, that's the whole idea behind D350. Europe is now also adopting 350 and even Asia, and Japan especially, is looking at D350. They, too, have the same kinds of problems. They are working in a much more complex world than you might think. A lot of things to look at with Japan is that they are there and we are here and they seemed to be doing things faster and better, but they have the same kind of problems that we do, because all the companies are competing with one another. So its not a panacea. The D350 is one way of getting there. We are developing standards and the next phase is training and certification to use the new software technologies and then, of course, software development. Now that's where all the individual commercial companies have to go out and spend their own money to develop the software to adapt to this D350 format, which means a lot of resources and a lot of money spent by the company. Yet there is already intelligence out there that will help them develop that, those are the people that really need the help because they will speed up their transfer. It will make them more competitive faster. The next thing will be implementation. Implementation for all of these companies to use a common format.

If you look at developing a product, everything seems to be against the poor company that is spending the money on a product. They invest a lot of money and they don't even know if they are going to have a business. They invest every cent they have. Our government has to make it easier for them to spend their money and, knowing that they are hanging out, to protect them somewhat. I have seen too many companies put their entire funding, their whole life into a product and they run out of money right at the end. Then an outsider comes in and takes it. They pay them off and they've got the product. It happens over and over again. There has to be some protection built into our own efforts in developing products, software, robotics and everything else that gone along with it. We have lost too much technology to the guy that has the big bucks at the end of the line.

Steve Babcock: I'd like to make some comments about what I have seen and heard in the last couple of days about the whole process of taking technology and using it. First of all, the reason, from what I have seen and heard, some real good, interesting ideas, ideas that I think some day could very well be applicable to our kind of needs. However, I think the big problem that we have and was somewhat alluded to here by a couple of speakers, and that is: is it the right technology? And more importantly, are we ready for it? We've made attempts and other companies have made attempts, both in aerospace and automotive, to put technology in and often it is put in either too early or it is put in a fashion that we don't understand well enough, and eventually we have to take it out.

What we are trying to do at Rocketdyne is to go back to fundamentals, try to understand what it is that we have today in terms of processes, really get a basic understanding of what we call "continuous process improvement," and once you understand what you have, then you can address the question of technology and where does it fit in. I think that in many cases, ideas, especially ideas that come out of the laboratories, are just that: they are ideas that may work in a laboratory but aren't really ready.

The other observation is that it takes time. It really takes time to take an idea and make it usable, to get it ready to actually use in production. A lot of people aren't ready to accept the timetable that it takes to get it in. I will reserve some other comments for these specific questions until later.

Bruce Brock: I share many of the same observations as my panel. Let me explain a little bit about my background. I am not an expert in technology nor an expert in technology transfer. However, I am a senior executive in industry and I know how to manage a business successfully to be a global world class competitor. My knowledge of United States R&D agencies and activities has been very limited, but I too, like several of the panel members, came on Tuesday to listen, observed and ask questions. Read all of the IPE papers. While I am a lot more knowledgeable today than I was three days ago, I am still not an expert in technology or technology transfer. I have some observations similar to Ric's and Steve's relative to the amount of technology, that's awesome to me. I just could not believe the amount of technology that we have in this country. I was sort of aghast at the variety of objectives and strategies that each of the agencies have. I was extremely upset by the duplicity that I saw.

I am not trying to blame anybody for this, but I don't know how many presentations I heard about robotics, data management systems or manufacturing technologies. I think every agency that I talked to had very good objectives and strategies and are probably doing what they are chartered to do. But, it's like in our company, years ago when we had a saying that we were 40 divisions looking for a corporation. Today we are far less divisions—maybe 20-23 divisions that as a corporation has a focus on being a world class controls company. We have a linked strategies, linked visions, and as Steve said, we have a visions and a strategies to transfer technologies based on market analysis. The observation that I make here, like many other panel members, is that the panel and labs have a lot of good strategies, but not a whole bunch of visions; a lot of good objectives and a lot of smart people, but there seems to be very little, if any, inter-agency linking of your visions and your strategies or objectives. It's an observation I'm sure there is a lot of linking going on, but, I was appalled at the amount of learning that all of you were doing at the same time I was. And of course, that's one of reason why you're having this second annual symposium, so you are trying to address the issue. I think that another aspect that I would like to touch on is an observation measurement. In the corporate world, in industry, if you do something, you usually have to measure its results. You have to somehow determine whether or not you are on the right track so you can make modifications or you can make the continuous process improvement to achieve your goals. I don't see the agencies having good measurements for the success of what they are doing, measuring their outcome, feeding it back so that they can continually improve. Along with the independent charters and the non-linking visions lack of good measurement seems to be another issue. In summary, the Labs have some good strategies and objectives, but are not linked between agencies, and they are certainly not linked to industry.

Dick Lopatka: In most cases I agree with the comments made. First of all, I would like to acknowledge the effort of the people putting this conference together. NASA and the others have to be complimented on taking on what I consider is a very difficult task. I think they have done an admirable job and putting this effort together. It occured to me as I watch this happen and watch the presentations and the dynamics of the audience, that this is not a natural act for the agencies.

But in fact, there is a message here. This is a reflection of the total problem in this country. We really don't work very well with each other. We have trouble deciding on the frameworks, the infrastructures, on who's going to do what, and so on. We need to keep working on this. We have got to keep doing it, doing it and doing it until we learn how to do it.

Relative to the subject of IPE - — intelligent processing equipment, we have so many acronyms now it is hard to follow - - but I don't have any doubt in my mind that this is a critical technology area. How it breaks down into sub-components of robotics, censors and controls, I am not so sure about. There is a broad systems problems here, and it's a subject that we have to work in total, both for our own federal activities and needs as well as for industrial activities.

We found the right subject to play with and test ideas with. However, I don't think we've got a technical structure yet to go after and attack. I saw lots of elements of what it is we need to do. I saw discussions about our gear capabilities, our optics capabilities in this country and how we are basically losing those capabilities. I saw discussions about some of the key components like controllers, next generations controllers. There were IPE discussions that revolved around processes like welding and deburring and chamfering. But what occured to me is that this isn't glued together very well, and comments about uncoordinated activities is very much right on track. Those activities need a much more critical mass of energy, coordinated energy in our country in order to compete with the world efforts in these activities. We are not going to get there with little pieces of effort that are almost anecdotal examples of how we could do it, when other parts of the world have very sizeable efforts, order of magnitude efforts over us in these activities. We've got the right subject, we've got the start on trying to look at it and attack it, but have not gotten very far into solving the problem.

In fact, I think there is a little bit of a trap we may get ourselves into by hearing presentations and stories of some of our examples of success. We could fool ourselves into thinking that in fact we've got the big problem covered and we really don't. To me this whole subject is like an elephant — - we are putting our fingers on it, touching it here and here, but we haven't quite recognized it yet. It's not clear to me, for example, in terms of all the dollars spent, how much of it is really useful to the industry, how much does the investment really add up to that has some impact on industry? We really haven't done the inventory and sized up the problem to understand what the real size of our effort is and what it needs to be. This coordination subject is a big one. I think fundamentally, we are not doing well at coordinating our efforts. I would like to use an analogy from sports. To me, soccer would be a good game to look at in this business. The world is playing soccer. Japan's MITI in the economic community is a well-oiled, structured, coordinated effort like a soccer team. People play their roles. They have a goal, it's clear what their goal is, they know where the net is. They are all kicking the ball and each person has a sense or each agency has a sense of what they are doing in terms of a team, a goal tender, a forward or fullback, etc. They have an orchestrated approach.

Our approach, whether it be the national labs or industry, is closer to how one plays soccer when you bring your five-year old son or daughter out to the soccer field for the first time.

Those of you who know something about soccer, know that you start your junior teams and the soccer players all show up and you put everybody out in the field, and you tell them to go kick the ball. Eleven kids run to the left as a mob and then eleven kids run to the right. And the entire game is played with a mob of people just kicking the ball around as a mass.

Compare this to a team that knows where the goal is and each person or each player on the team knows its position and its goal, and they happen to know where the goal is. As you know, the chances of getting the ball in the goal are much higher. We really don't, whether its our federal agency or industrial wise, have an articulated common goal. So we don't recognize or acknowledge what the goal posts look like, and then once we understand our goal, we don't really have a team approach. So we are basically a country that's playing soccer at the pre-kindergarten stages when others in the world are at a level of sophistication where they have a team approach. They understand their goal and they are working to be very, very, competitive. The fear is that we are heading to be number three in the world in playing this game of economic soccer.

Ric Davis (moderator): What I'd like to proceed to now is trying to develop some specific answers to questions one and two. I think a number of our remarks have already hit on answers. It's very difficult not to keep it out of your comments. However, to be fair to the panelists, this time I am going to reverse the order. I am going to ask Dick to start it off and the first question I would like to know is how is he going to organize the government?

Dick Lopatka: Well, I don't know if I know how. Matter of fact, I'm not sure if the government is the place where the technology transfer or most of this problem has to be solved. So I really don't come here with a bias that the answer is in our federal agencies and our labs.

Ric Davis (moderator): I was a little a facetious with that comment, but I did observe that that's one of the issues that answers the first and second question- -was getting organized.

Dick Lopatka: Let me in a brief way talk about why we're not going faster and why aren't we using the technology. I think we are not going faster because again, we don't have a critical mass on these subjects. Because of our somewhat uncoordinated activity and potential redundancy as stated, we lack the critical mass that is required to go at the speeds required. This is fundamental to the program. We lack the critical mass because supporting industry is not the number one priority of the agencies we are hearing from in the last two days. It is, at best, a secondary priority. We have to deal with the issue of priority and the issue of critical mass in order to deal with issue of why we are not going fast enough.

Why aren't we using this technology? Quite frankly, to be cynical about it, it's trickle down technology. It's technology that was developed for another purpose, and people come along and say, "oh by the way, why can't you people in industry use this technology—it's good stuff huh?" This technology is to support the missions of the agencies that we have here. By the way, I think that is correct. The first priority is to see that the agencies here have the technology to meet their missions. And the real issue is, will this trickle down to their secondary priorities yield enough for the industrial base. We are not using this technology because it was not designed to be used by industry. It is not packaged, it's not fast enough.

We see technology that has promise, but the path of getting it from promise to implementation has a lot of obstacles. The technologies we see manifest themselves in certain applications. These applications aren't the applications of industry. Technology has to be repackaged, restructured, made cost effective, put into a product line. So there is quite a distance between seeing the raw technology or seeing the technology manifested in an agency's product and reaching an industrial product. There is no gimmick that takes the technology and a short time later it is in place in industry. There's a lot of work involved.

Another factor that affects why we are not using it is the speed in which it is developed. In the industrial world, speed, time to market, competitiveness, has a lot to do with how fast you bring technology into the marketplace. If you can't play the game of time competition, you really have a problem playing in the world of industrial R&D, because the product cycle is moving very, very, rapidly. So if there are bureaucracies, if there are proposals and procurement processes in the way that take several years out of the process, you can't play. If you can't count on the technology in terms of being there year after year, you can't play. If you can't turn it around, you can't play. There are some really serious issues in the way of taking this technology from the agencies and making it a big part of our commercial industrial technology basis.

Bruce Brock: That was very well done Dick. I would just like to say that I agree with most of what you said. I would also like to make a couple more points. I don't think there is one answer to these questions. I would like to start by explaining technology itself. Aren't we developing technology pretty fast? I saw in the last three days more technology than I have ever seen in my life. Someone reported that the government labs for $80 billion annual budget, and there was $65 billion worth of technology in inventory. That's a lot of money. That's a lot of technology. I think we are developing technology at an adequate speed. But what kind of technology are we developing? We are the world's best in space technology. How applicable is that a commercial needs? Can we use it today, can it be migrated into our products on a short cycle basis, as Dick said? I am not saying it is the wrong technology, but is it the right technology? It doesn't appear to me, to be commercial technology. There's no question in my mind we must be the world's leader in developing aerospace, and defense, and very sophisticated technology. But that is not what our world competitors are developing.

They are looking at a time horizon, a short cycle time, and they are integrating their technologies into products or using it to make the products. I think we are using our technology, maybe not to the fullest extent, maybe because there is not a great deal of coordination between R&D and industry, but it might just be the wrong technology that we can't use today—maybe ten years from now. There isn't any solution to it really except that there has got to be a greater focus on the market analysis of what commercial technology is needed for the time horizon we have today. It was impressive to me that the most analogous or the most linking objectives and visions are in the Department of Agriculture. They know what the farmers need. I thought that some of their objectives were right on, and think that technology is probably transferring pretty well because it is very applicable.

Steve Babcock: I would like to add one note in particular that addresses the first two questions, and that's coming from more the process side rather than the product development side. I think that while the technology may be out there, it may not be in the form that we need it or may not be exactly the right technology, I think internally to most U.S. companies, we don't put our priorities maybe where we should. As an example, I would imagine that most companies are like ours, where we put probably 80% of our R&D effort into product development and 20% at best into process development. If you take a look at the rest of the world, I think you will see that in reverse. I've heard numbers like two thirds of R&D goes into process development in Japan and a third into product development. So in some respects, in regard to putting technology on the shop floor, we aren't putting our money where we should. There is a slow change, that's a culture change, and I believe that will come about as we begin to realize the importance of taking money and putting it into the right place. The other comment I'd like to make is in regard to the idea that nothing succeeds like somebody else succeeding. In other words, to get a company interested in pursuing a specific technology, it is often better to say "hey, it has been used somewhere else and therefore lets transfer it into our own company." The problem that exist is that although the technology may be developed in a laboratory or developed in some cooperative arrangement between a laboratory and a specific company, getting to really understand how that company uses that technology is very difficult. You may be able to go in and see a demonstration, but in reality the company that's using that is really keeping it under wraps. You don't get a chance to really understand it well enough to be able to see the link. I think that is something that, again, is going to have to be coordinated more by the agencies, but we find that to be a real problem. We get an idea, we hear about something, but to really go out and understand it well enough to be able to take it and use it ourself, that's a big link that needs to take place there.

Vern Solberg: The United States has never run out of the commodity of innovation and we have adopted technology, it's been proven. I like to put ourselves another hundred years ahead on how we are going to look at the last 25 years in the segment of history. 25 years - - imagine what has happened.

We didn't have IC's 30 years ago as we know them today. 25 years ago they were too expensive for commercial products and now we couldn't build most of the products we build in electronics without an IC. What has happened to the IC, it has gone from a single segment to a complex applications specific product. But now we have one IC that can perform all the function of a huge computer. That's innovation. It's adapting technology, it's evolution. I think that is going to continue. It all started with a lot of government money developing these products for space applications and miniaturization. The same thing is going to take place. Now it's taken a long time to come to where we are today and now it's amazing now that government is adopting some of the technologies that the commercial world has really come with for yet new products. The main thing is the environment. The difference in the typical commercial environment and the government applications is quite different in that they often have to be hardened or be exposed to the extreme temperatures or what have you. Those are the differences, but the technology is still there. I see an innovation that continues. Even though it is not always government funded, there is some incentive. This last week, high definition television was demonstrated by a U.S. company. It met all the requirements that the U.S. had put on high definition television. It wasn't simply an adaptation of an older group of technologies. It was a new technique and they proved it did work. My hope is that we won't give it away.

Somehow the U.S. can capitalize on the innovation and maintain the innovation and make it worthwhile for these companies to produce it in the U.S. and then at the same time give them a stronger position in the world market. And that goes with any kinds of products. We have been too easy to pass along technology, helping out the other guy and we are destroying our own industry. The commercial industry right now is in a lot of trouble. We can't always rely on the technology bailing us out. We have to bolster up the industry. If it means tax incentives--whatever the things that can be done by the government, that's helpful, but innovation is really the key and it's right here. We are not a bunch of copy cats. We are innovators and we should capitalize on innovations.

Steve Scarborough: As a response to these two questions, I brought along one view-graph (please see next page) of what my Sensors and Systems Development Division does in terms of transferring technology. I think that we have a lot of the same kinds of problems that every company has. If we are going to try to come up with a better way to transfer technology, maybe some of the issues that I run into on a typical basis are things that we need to understand.

I don't use this view-graph for this kind of a discussion very often, but I think it might work pretty well. We call this our Sensors and Systems Development Center (SSDC) engine. I am in a corporate research and development center. our job at this center is to think five and ten years ahead and come up with innovative products that have differentiators and that are potentially commercial viable. Every company here is a company that is in business because they need to make money. If they don't make money, they are not in business anymore. That's different than the Government Labs and it is very important to realize that, and what that means.

If we are going to do our business correctly at an applied R&D center, I need to understand every one of the divisions that are my customers inside of Honeywell, what their customer set is and what the product line is. We have a wide range of needs, Residential sells thermostats, costs are critical in this market. Industrial process control is in the hydrocarbon/petroleum, the pulp and paper, fine chemical; food and pharmaceutical businesses. There are different products and needs in every one of these division.

The first thing that we have to do is develop a very strong relationship and understand those Divisions and Customers. After we understand customers and what the product needs are, we work with every one of our divisions, and we understand their five-year product plans. We understand where their technology voids are and we understand what the competition is doing. This is absolutely critical to us because we have something that we can sell that is better than the competition, or we are not going to sell it. We also understand that we can't sell technology, it has to be a solution to our customers' problems.

We have two types of programs to develop product concepts. Internal development programs called technology development projects, is where we develop long range concept solutions. Forty percent of our business is involved in outside contracts, typically with the Government. So we are working with SemaTech, NGC, NIST, DOE, EP, DARPA, etc.

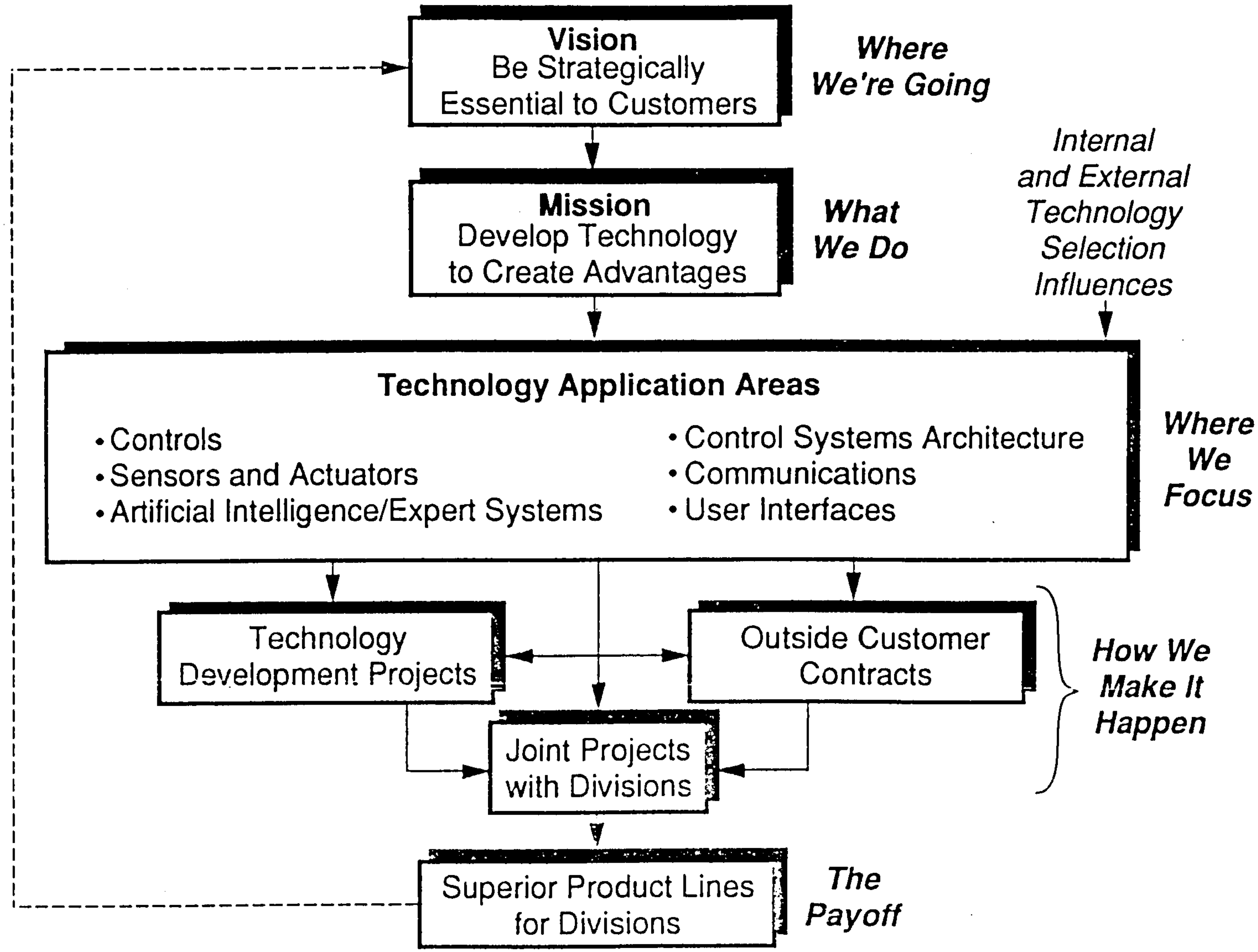
The way that we transfer technology to the divisions is with a joint project. The most effective way to transfer technology is to have a champion on each side and has ownership.

So when we get a concept solution that's going to fit into a particular division's customer needs, we find a champion in that division and put together a team of people from both organizations. Both teams work together on the problem and then transfer that technology using concurrent engineering techniques. If your don't have a very difficult time transferring any technology at all.

There are other things as well. We must have a commercially viable product. Time-to-market is a critical issue. Any product that we are going to sell eventually has to meet ROI goals. I work in a program right now where we are scraping up all sorts of technology to put into products. With this technology I can probably come up with ten strong product potentials. Because of ROI and financial constraints, we probably will be able to afford to develop two of them.

Legal constraints and Intellectual property rights are a big issue. There are programs now that we've won that just because of the intellectual property rights issue, it might take another twelve months before we can initiate on that product development. Therefore, all kinds of issues are involved with transferring technology inside of Honeywell into a division. Pushing outside technology through the same path is more difficult. I believe the Government must put together an organization that has the charter of developing and transferring technology to commercial industry. Their process should be similar to the process I described with the SSDC Engine view graph. Working effectively in a concurrent engineering team with co-ownership is the key.

SSDC Engine


Vision
Be Strategically Essential to Customers
Where We're Going
Mission
Develop Technology to Create Advantages
What We Do
Internal and External Technology Selection Influences
Technology Application Areas
• Controls
• Sensors and Actuators
• Artificial Intelligence/Expert Systems
• Control Systems Architecture
• Communications
• User Interfaces
Where We Focus
Technology Development Projects
Outside Customer Contracts
How We Make It Happen
Joint Projects with Divisions
Superior Product Lines for Divisions
The Payoff

Charles Hamermesh: Much of what I was going to say has been said already so I would like to make three comments. One is in relation to government technology I love to use analogies and so on and my favorite scientific cartoon is of a bunch of guys in lab coats standing around the table on which there is a pile of white powder. And the caption is "Yeah, but what do we do with the dehydrated elephant?" Gentlemen, the government has produced a huge number of dehydrated elephants. I don't know what to do with them! I'll leave it at that. Second comment. We have ignored a process R&D and not only in our programs. Let's go back to academia.

The day that chemical engineers discovered that they could sit in their office and run their computers and calculators and not get out on the floor and know what unit processes mean, is the day we got into trouble. We have to understand process because process and product are tied together. Quality and everything else (cost, volume), relates to that and we haven't done enough. It begins with what is taught to these people in the universities. There isn't enough of that. There are so many courses being done on advanced things and so on that we have forgotten the basics. The last thing I'd like to get to is to go back to Dick's comment about soccer, finding the goal.

I am going to bring up a term that is repugnant to technologists, and I would like to include us all in that same category of being technologists regardless of whether it is controls, materials science, aerospace, or what have you. And that is market research. The only way to find the goal is by market research. What Dick did with his kids, he pointed out "you see that netted thing down there? That is where the ball suppose to go." Now, do we really know. Where the heck that goal is in these different areas. I don't think so. I think we need a significant market research program to find these possible areas. Now if you do that, what will happen?

Well, I keep on reading that the fastest growing area for employment is small businesses. How can small businesses find the technology which fits their area unless you provide them the market research which says to them, "hey, there's something out there that you can use in your area." I think this is very significant. The companies up here are multi-billion dollar companies and yet they are not the ones who at least from the literature that I read, tell me will be the place where employment growth will take place. And right now, we need jobs in the United States. Level this playing field by presenting this information to the small companies.

Hadi Akeel: Addressing the first question about the speed by which we develop technology, and asking ourselves the question about what technology we mean to develop, we understand that the U.S. Government could spend huge sums of money for strategic and defense objectives, that much of that technology would be directed to very specific targets that are not necessarily related to the general productivity of the Country or the prosperity of the industry in general. So there are definitely a lot of development that are being devoted to very worthwhile objectives that we need not involve ourselves with in here. But there is definitely another part of that development that is aimed primarily at benefiting the general industry. I may include in that the money that may be spent on the space industry rather than the defense industry. Of course, some of that is defense related as well. But the very first objective of the space program was that of having a major national goal, and in the process of obtaining the goal, the nation develops technologies that the general industry needs but could not afford to develop on its own. Thus, the goal is a means to an end focused on benefitting the general economy of the country. And maybe that is where we may look, though it represents only a part of the $65 billion or $85 billion that the Government spends yearly on R&D. There is a lot of technology out there, whether it was developed fast or developed slow, is possibly not the issue. Maybe we have made up for the slowness of development by overwhelming it with funds and resources to get a lot of it. So I don't really agree that we are developing slowly. The rate is possibly very high - - it looks like it's far beyond what the industry in general can absorb and we have always seen statistics and discussions in the literature on that. It's a matter of efficiency and focus. Rather than say, "are we developing it fast or slow", we should be asking ourselves, "are we efficient in the development of technology?" and, "are we focusing on the right technology?". I say we are very inefficient. We are inefficient for several reasons and I am going to address the reasons of this when we talk about the third question of what to do about it. The inefficiency in here can show itself in a duplication of efforts but more relevant is the question that has been addressed before about the goal and about our process of developing that technology.

I like that analogy with soccer because I played soccer all my life. But I'm going to take football, which makes more sense around here. I think what we are doing here for our developments and our research, is that we are trying to develop the field goal kicker who can kick the longest field goal. We forget that the other team is playing on the ground and pushing yard after yard and beating the hell out of us, and all we are doing is trying to find that field goal kicker who can kick it from the mid-field so maybe we can make up for our deficiencies. The other guys apply incremental improvements, enhance the skills of the individuals and have everybody know where they stand in the game. They know this will get them to the goal at the end and they will be ahead. And I look at that and say we need to see first if we do have a goal, and we need to define the process by which we get to that goal.

We look at evolutionary developments, that's evolutionary advances, and that's great. I think a certain percentage of efforts must be devoted to revolutionary innovations in research, basic research, and that is the objective of the National Science Foundation and the academia in general and many of the research oriented labs. But when we look at money intended to get us ahead and improve our competitiveness, we should be looking not necessarily at the investment in high innovations, but at innovations that come from that particular segment of our investment that provides applied research and development. And this means processing and manufacturing. As one says in my original culture, I came originally from Egypt, that the birds flock where there is grain. Well there is a lot of grain that is being thrown around by the Government here and I don't see any birds, very few birds, looking to see that grain. Why is that? One of two things. Either it is the wrong grain, it's not the right feed for us., or, that so many traps have been put around that the birds have learned not to come. And I think it is a combination of both.

Robert Becker: I have no clever analogies to football, soccer, birds or elephants but I am going to try to attack it more on a pragmatic approach being a small business representative. By the way Charles, we are not all multi-billion dollar companies represented here, maybe some day. We've got the ear, fellow panelists, here of the Executive Office of the President - Leo Macklin representing the President and Dr. Suren Rao from the National Science Foundation, therefore I think we should try to get pragmatic. We've all spoken here about the things that are wrong or we've talked about having a goal. But pragmatically, what can be recorded in annuls of time that will actually be and make a difference here today. I want to try, that is to give three such solutions that I have thought about in the last months since I have been asked to participate on this panel. They center around three problems: One is SPEED, the second - MONEY, and the third is COMMUNICATIONS. I am going to attack each one of those separately, but very quickly. We've talked about a goal, I started off by talking about the fact that we (at In Tolerance) are not a TQM company (Total Quality Management), but I rather I believe in TQ/PI. You will see that if you ever came to our facility in Cedar Rapids, and I invite you all. Total Quality Process Improvement and I am happy to see that a couple of our panelists have mentioned the word process. The process according to my TQ/PI philosophy, start with the customer. And again other people here have talked about market research. You've got to go to the customer, understand what he needs and chart out those things that make the greatest impact and attack each one those elements slowly, methodically, measuring and improving each step of the way. This is not being done in general within business and government.

I challenge each on you in the audience and my fellow panelists to go back and ask your own companies, does your departments really have a measurement of performance for even the very small detail work that goes on within your companies? I'll give you an example of waste... We work for a fairly large military contractor, making many parts for them. I have a part that I have made for years and years out of 172 HH beryllium copper. But now that 172 HH beryllium copper is no loner available. It comes in only 173 copper. Fine you say, tell the contractor I can't make it for you out of that, I can make it for you out of 173. He's got to put in an ECN (Engineering Change Notice) up through his bureaucracy. It has taken him three months and he has yet to give me back a change order requiring the 173 copper. Why should it take so long? Because he has so many infrastructures he has to get through to get sign-offs, including the DoD because those parts have already been accepted as a 172 HH on an old print.

So we have not done a very good job within our own infrastructures both small business and especially the large businesses at improving the productivity. Another philosophy of TQ/PI involves the internal customer not only the external customer. Anybody who has been taught the classic teachings of Deming recall that you have to realize that each time up pick up an internal phone within your own company or pass a piece of paper on within the infrastructure it is enroute to an internal customer and one must constantly improve this quality of process. Therefore, the speed of the process has got to be the major goal of all our corporations and our agencies. How we internally do things will affect how our external results are accomplished. I believe that this country needs to initiate TQ/PI, taught from the schools to the boardrooms so we can start looking at things methodically, statistically charting utilizing SPC and making continuous improvements; For the one goal of speed and thereby quality also cannot be ignored. Total quality "management" does not talk only about quality, it also involves speed. If the goal is speed, a catalyst must be MONEY. To help initiate these improvements we need to bring back an old friend to manufactures, that being Investment Tax Credit. What happened to the 10% Investment Tax Credit on capital spending? It was stopped a few years ago, but why? I believe we should bring that back a 10% ITC credit on capital for the year the capital equipment is purchased, I also believe we should change that from 10% to 15% ITC for any machinery or capital in which 50% use American made components. Why have we dropped this? Why aren't we attacking this issue with our congressmen? It will give a push, especially to us in small business to re-capitalize our companies where many rely on World War II vintage equipment.

Second, on the line of tax incentives, I believe we should be given an investment tax credit for renovation and retrofiting "old capital." That is, if a retrofit involves over 50% of the book value industry should be able to get 10% RTC (Renovation Tax Credit). In other words, let's not encourage our throw away society to dump anything old. Sometimes it is not possible, but where applicable we should retrofit and try to revitalize at least back to working spec. Many of these non-spec equipment pieces are not so old by the way. Equipment five years old these days require updating to maintain its productivity. Again, I speaking of bringing back the ITC of 10% or 15% for American made equipment. Thirdly, on this money side, 15% tax credit on (what I am going to call) ETC that is Education Tax Credit. We talk about that we have to re-educate the American work force, why not give some incentive to the businesses to do this? Here I am, for example, a company that last year, spent about $4,000 dollars directly to our community college to train our people on SPC, Deming teachings and the like. Except for the standard deduction as a business expense, there is no other tangible immediate encouragement. I think the government could be doing something right away to help here.

I propose a 15% ETC (Educational Tax Credit) that is, if I spend over 0.1% of my gross revenue on an education system delivered to my employees, and not necessarily just the management, then the business should be given a 15% Educational Tax Credit off the bottom line of the tax return. That's something the government can do - its tangible and pragmatic. Again, I am talking from the perspective of a small business owner. We [IPE Review Panelists] have got to give some direct inputs, right now, some goals, to accomplish this change we desire.

The third problem I've outlined is COMMUNICATION. And thereby, again, reiterating the goal here is SPEED & TQ/PI. MONEY, the incentive, and COMMUNICATION is the bridge between communities and separate cultures.

We have got to develop a better infrastructure of communication within our companies, agencies and the connection between them. Again, I go back to what I said earlier, that is, I found at least three maybe four different companies or agencies out there [on the Tech 2001 display floor] delivering data base information reaches connecting to God knows how many databases all using their own separate language to look up and search things. Why isn't there one central spot where we can all deposit and retrieve information on tech transfer projects that have been sponsored by the government or by public consortiums. There should one agency which sole responsibility it is to document activities and progress on such research projects. Too much information is not getting written down, information that the tax payers are entitled to. I have heard often that one intent is to not complete a project or software and thereby keep it from becoming public domain.

No monies should be extended without this check and balance of complete documentation to this sole depository of information. Once within the system the access should be open to all (of course multiple security screens is a necessity) via a PC and modem. The information could include a neural network, of such, for contact names on a particular project. There is no doubt, as some have spoke of, that individuals transfer technology not computers via some RS232 modem; It is people talking to people and these people will have to be able to find one another once they leave a project. Scientists and engineers have a tendency to move around a lot in this country, that is, to different companies, and I believe there is a need for a new "neural" network. If an engineer or group of engineers and scientists have signed on a project, then their name(s) are connected with that project in the database, there must be a permanent path to find these individual(s) later - should someone want to contact him/her. It would be as a mail stop, you should be able to find him wherever he moves or goes. This ability to find information will create a new kind of communication, one in which money, should be a motivater that allow people to benefit directly from the application of new technologies. Those are my three rather pragmatic "small business" approaches for trying to get some agenda whereby we can make some real progress, TODAY. And if not today, WHEN?

Ric Davis (moderator): What we plan to do, after the break which is coming up shortly, is to take on the next question. We have been standing here saying what's wrong with the system, now let's present some solutions. Bob started to presents some solutions. We would like to hear from the panelists first about what are the solutions. Once that done then we will open for questions or observations from the audience.

Ric Davis: Let me try to make my final remarks relative to the first couple of questions. I was pointed out and I think one of the key issues is that the technology being developed is being developed for different reasons. I agree a little bit with David, that the reasons for some of the technology is for the agency needs itself, not for technology transfer to the general public. And that is as it should be. So it doesn't mean that all the technology being done should be aimed solely at getting it out to the general public. However, it was also pointed out that the challenge now is how to take that technology and identify within it what really can be transferred out to the general public. Part of the problem with that in my mind is the vast array of data that exist there or what is there available for possibly picking up as you say nuggets, David. The problem is that most of small industry doesn't have the resources to go tap that source. They need help to understand first, what is there. Communicating what is there is an issue. Where do they go, where do they find it, how long does it take them.

Once there, they need to get some help relative to how to apply it. How do I put it in to my particular operation. Because usually, it is not in a state that they can just take and put it onto to the floor. It needs some developments, some modifications, some applications.

So those are some of the barriers that I see. At this point let's have the ten minute break, when we come back we are now going to the test. You have said what's wrong with the system," now what we would like to hear is "here's how you can go fix it."

*****B R E A K*****

Ric Davis (moderator): During the previous session we were joined by one of our final panelists, planning to participate on the original published schedule. Michael Cronin at the end of the table, would you please introduce yourself and your company. Feel free to make a few remarks that may help us understand your point of view before we move on to question three.

Michael Cronin: I am pleased to be here representing both Automatix Inc. as chairman of its board and Cognition Corp. as CEO. Sorry to be late, I did not get word of the schedule change until now. Briefly, Automatix is a 12 year old company which I helped co-found to develop and market CAM products including intelligent control, vision and robotics. We grew quickly to 450 employees, almost $30 million in sales and became a household word in the field of AI and robotics.

Now we have shrunk to 42 employees, $7 million in sales and very few people talk about us. At the peak in the mid 80's there were over 20 U.S. companies developing and manufacturing robot systems. Now there are about 3. We at AI restrict ourselves to robot software and control only along with industrial vision products.

What happened would take an entire session to explain. In summary, the Japanese did not cause the problem and the game is not over yet. It's just being played on a twenty year time span (similar to the story of lasers).

More specifically, I am pleased to note that Automatix has been profitable for the last 5 quarters, is growing slowly but steadily and is using government initiated technology transfer as a strategic R&D weapon. Cognition Corp. is a new company (spun off from Automatix) which is pioneering in the development of software for performance modeling designs in order to optimize function, quality and cost, etc. Technology transfer has been important to Cognition in the CAL's program with General Dynamics, Picatinny Arsenal and Wright Patterson AFB.

Recently, we have increased our technology transfer efforts by working with GE and others to provide knowledge capture for composite design and manufacturing processes. My comments on technology transfer are confined to three specific areas:

First - Basic Research: In addition to publications in referenced journals which we monitor, I believe the government should increase its marketing efforts by grouping the research reports by applicable commercial field. For example, research on sensors, smart motors, AI, grippers, etc. should be reported under the robotics group.

Presenting outstanding papers or summaries at relevant trade shows for example Autofact or SME's robot and vision shows.

And last, arranging government technology transfer conferences. Not so much around an agency show such as NASA, but around technologies or markets such as biotech, robotics, intelligent controls, etc.

The guiding principle is that small companies cannot conduct private research, but must be aware of major developments in the field.

Second - Technology Transfer and Acceleration: The SBIR program is working! Small companies can and are using SBIR's to supplement internally funded R&D. One caution is to monitor the recipients of SBIR's and weed out those who make a career out of SBIR's with no commercial implementation.

Third - Consider the Adoption and Funding of a National Goal: I do not recommend an industrial policy or for the government to set commercial strategy. However, the country and industry has benefitted from national goals such as winning WWII, containing Russia and landing on the moon.

Why not additional major goals such as:

- An electric CAR
- an Aid's cure
- High def TV

Then we as a robot or software company could put together our own strategy to participate in the new industry. Thank you for the opportunity to catch up.

Ric Davis (moderator): What I would like to do now is have each one of the panelist give a single suggestion of a solution to some of these problems. I would like each panelist to pick different solutions so that we can get a lot of new ideas on the table.

Ric Davis: What I would like to do for my solution is look down stream a little bit. I perceive this as a situation we are facing now that is not going to change. There will continue to be a large amount of technology being developed by the government, for the agencies purposes, for the government purposes - - it will be there all the time. The question is how do you get that out to people that can use it? What I would like to suggest is that in the long term, our solution for that should be academia. We should ask that indeed the colleges take on that chore of first taking the technology that does exist and getting it into their curriculum, teaching it to their staff and studants. So that the new graduates coming out of college will have that exposure. They won't have to be searching for it. Secondly, another part of the academic challenge should be, to be able to describe to technical graduates what the system is that's out there that is producing this data. Where it is, how you access it, what you do with it. So when they graduate and they go to a company — and they won't say "okay, how do you get to it, what do I do, where is it?" I would suggest that you do that by a grant. Have a grant to a college put together the strategy of how should the nation do that, how should it be achieved? And so that is a long term solution which I think would solve one of the current problems.

Bob Becker: Well, I am not going to be redundant from what I have already said. T.S. Eliot wrote that "We will not cease from exploration, and at the end of all our exploring, will be to arrive from where we began - and to know that place for the first time". Now to make an analogy of that and technology transfer will be tough, but here it goes... I submit that what we need is a "Phase IV" development concept, that is, after the technology has been proposed, developed and implemented in some way, we then should have to bring it [new technology] down to small (or possibly medium) business to make it applicable-MARKETABLE. It is as Eliot said 'to take that home for the first time' and let it become applied to the real world. This "Phase IV" should even possibly be a requirement to some of the federally funded projects. We [at In Tolerance] were fortunate, to be given the opportunity to become involved with the RAMP development program, thanks to the Navy and FEMA for selecting us in this cost sharing PRISM case study. It [Rapid Acquisition of Manufactured Parts] had a Phase III type of development done within the South Carolina Research Authority facility. Though when we actually brought the software and hardware in house and applied it (in a phase IV approach) to the pragmatic rules of a small business environment (as a manufacturer) it was only then we found many things had to be changed to make it functional and applicable. Much of the software wasn't quite right. The hardware requirements were reduced. The "Fifth Generation" software wasn't as "Fifth" as we would have wished it to be (maybe a forth and a half). So we've seen that by getting it [new technology] in the hands of people like us, in Small Business helped the project take on a new pragmatic approach. (And by the way, we were required to pay a cost sharing fee along with donate many man-hours to have this "Phase IV" Case Study performed at our company.) But I think we have given back a more applicable product in return. So, again to paraphrase - "by bring it back home [to small business] you may know it [your new technology] for the first time". Thank you.

Hadi Akeel: I have one suggestion to make and I am going to just give a couple of examples before I get into this. We were approached by a large aerospace company looking for industrial applications for their development. They came up with a control board and software to improve the performance of the robot by X%. They gave us a presentation and we looked at it and said, this is great. This is really one of the best things that we've seen in a long time. Even our latest development may only get us 60-70% of what you seem to have accomplished. How much would it cost?

They said gee, possibly if you go volume manufacturing and make about a thousand a month of these you can produce these boards at about $15,000-20,000 dollars a unit. Well, most whole controllers cost about this much. They just couldn't find a way by which this would be cost effective for us. The other example I want to make is that I sent for literature on a break-through that was brought to my attention by one of the Government labs about an invention. I sent for it and the first thing I got back was a non-disclosure agreement to sign for proprietary information and all sorts of things. And I did sign it. We sent it out and got very little information. It was enough for us to know what it was. And now, we are supposed to negotiate fees before we even know whether we could have a product out of this or not. Well, this introduction is to one of the proposals I would like to make. And that is to revolutionize the process by which Government projects for research and development are initiated, evaluated, assessed and approved. I'd like to see that process to begin by having the Government labs identify who their customers are.

The customer may be the Government, the customer may be the Navy, the Airforce or whomever, but if that customer is also the general public, which means the general industry, then the industry must be satisfied in the process of assessment of that project. The project must take into consideration the needs of that customer and what constitutes a successful outcome. That means also that the targeted industry for that particular development should be part of the evaluation process. Representatives of the industry should provide input into the initiation of that project, its targets, objectives, schedule, timing, rate of development, as well as its budget. And if there is a product coming out of that in the sense of an original research or a new development, that product must be assessed not in terms of its potential impact on the industry, which is always implied in most Government contracts, but on actually making an impact. There must be a target for the magnitude of the impact and then the success or failure of the project should be assessed in terms of its meeting this objective. I understand that some of the Government agencies do not have in their charter the support for, or to have an impact on, the industry. But how much is that stressed? How much of it is ascertained by the leadership? How much of it is part of the objectives that the project team must keep in mind and know that it decides the success or failure of the project. This process is very well recognized in industry who have to live or die by the success of their projects and make money when things come right or risk their livelihood if things don't go the right way. If the Government follows a similar process, then we may end up with the kind of development the industry needs, the right grain for the birds to flock to.

Charles Hamermesh: In may 1991, I spoke to the House-Senate Materials Caucus on technology transfer in the materials/processes area. I pointed out that a hez to success is this endeavor is to getting the proper market. I pointed out earlier that this required a market survey and that it should be funded ty the government so that companies big and small, have the same opportunity to be aware of the results of the study. Another important function the government can provide is disseminating information about the technology available for transfer. But, the limited know how of the audience must be recognized. I spoke about composite, most of them don't know how to spell the word let alone know what they can do. Therefore, you must begin with basic and explain to them what is the potential of the these particular controls or materials or processes. You can not start off by saying, this is great and now take it and go from there. It must be very basic to begin with because we are starting with people who are not very well informed. Now I like to add one more things and I hope you won't take this as a publicity blurb. But, we technologists, whether we are in government or elsewhere need a pipeline into the legislative organization. I am proud to say that a member of SAMPE was appointment a Congressional Fellow to the House Committee on Science and Technology. Dr. Steven Borleski, the gentlemen who has this role, would be more than glad to obtain input from both industry and government in regard to how this should impact the legislative approach of that committee. So I suggest that those of you who desire to make yourself available of this gentlemen's service, please help yourself.

Steve Scarborough: I guess the one recommendation that I would make is similar to what I have been talking about. We talked about the technology that supports commercial products is different than technology for the defense products, I don't think we should water down the various Government agencies with a multiple charter. I recommend establishing an organization that has the charter of working with industry to develop technology for the commercial market place. The Government, industry and the education facilities all have to work together as a team in this particular arena. The process has to be something like the one described earlier.

Market Research is absolutely critical and should not be done by the Government. The Government has to understand the results of that market research and what the constrains are on the technology. The agriculture department looks like they have been doing transfers effectively. Their charter is working the industry that they are trying to serve. That is an example of the kind of solution that we are talking about.

The Counsel of Competitiveness Report was worked on for two years. Every recommendation heard today is in there. It was prepared by very prestigious people. It covers everything from making competitiveness a national priority, to education to economics. My question is, what's happening to this report? What has been the effect of it?

Ric Davis (moderator): Steve, one comment. I think the closet thing I saw in the session yesterday coming close to your suggestion was the needs analysis that was being proposed and worked by SDI. Do you see a parallel there?

Steve Scarborough: The model? Yes, I think there is a parallel there, but again, SDI has a very specific job of developing technology for missile defense.

Ric Davis (moderator): But if you could replace that with the needs that you get out of the commercial side and let it drive it through that process, it might be a model that would work.

Steve Scarborough: There are things going on like that in the industry. The machine tool lab at NIST is similar. We must develop a team work approach and the co-ownership to transfer the right technology at the right time and there are ways to do that.

Vern Solberg: Strengthening the manufacturers capabilities in the United States has to be a priority. I think we let a lot of things slip through the years due to the cost of improvements process development—a big area that requires more than development. You can have innovative products but you have to be able to produce them efficiently. And that goes along with process improvement. Large companies can often develop a resources inside to do a lot of these improvements. The small companies cannot. There is a lot of agencies out there telling companies what they are doing wrong. . .[OTHER SIDE OF TAPE] happens day after day. There should be an agency or a team that can go in and help the small business man improve there product and improve the process, clean up their act, help them find the financing at a cost that is affordable. Its the little guy who can not go out and get the prime rate, they can't go out and get instance finance because they are the little guy. The big guy don't seem to have any problem. They get millions of dollars of credit just by saying they need it. So the little guy needs a little bit of assistance there and sometimes just a little bit of big brother kind of backing will get them whatever it needs to do the job better and thereby be more competitive. The little guy is losing out. SCI is the big guy, they do have the resources. We are one the strongest contract manufacturers in the country. But we rely on the little guys to supply us and a lot of them can't be competitive or they are going out of business so we are losing them, we are losing good share support. The end product of course is got to win on design and functionality. Its got be high quality, it has to be reliable, it has to be cost competitive. All these factors has to be met. I think we can do it all right here in the states without relying on outside services outside the U.S. I hate the term offshore. Its starting to be a real negative kind of a thing with me. I don't want to dwell on that but I hate to keep saying "well I guess we can go offshore if we want to be competitive. And that's how we lose most of our technology.

Steve Babcock: A lot of discussion has gone on about the small business and I totally agree with the suggestions made so far, but I would like to consenstrate on the big guys. There is a way I think to improve the effectiveness of transfer technology from the labs. There is a term that has been used this week a couple times called "networking." I think the model was an example of that. We have been pretty successful. I think of transferring technology by taking a team of people and moving them from our operation into the Marshall Space Flight Center having them onsight working on problems and then transferring them back. I would like to suggest that we continue to do that maybe with other agencies. But as an addition to that, there is no reason why we couldn't reverse that role and say lets take people out of the laboratories move them into industry and work right on the shop floor to take the ideas and work together as a network, as a team and bring that technology into place online so that the understanding of what the real problems are can be shared with everybody on the team. Then the specific things that need to be improved on can be back into their laboratories and work on that and then bring them back. I believe from my personal experience that would be very helpful in transferring technology more efficiently.

Ric Davis (moderator): Thank you Steve. It certainly is a unique viewpoint.

Bruce Brock: We are all here today because we are losing our global economic competitiveness. We are losing the game. And we have the notion that if we can take advantage of our technology base and our technology development capability, which is awesome, we can regain that competitiveness we are losing. I don't really have another solution, I think the panel members have already articulated many, many solutions that are viable. However, I think the counsel on competitiveness produced an outstanding document that I would encourage reading and the adopting recommendations. But I would like to suggest a parallel effort if you will and maybe continue with this analogy of a soccer team or a football team in just a second. The rules of the game are not the same anymore. In past, the U.S. made the rules of the game. Today we don't. The rules have change. When you talk about playing soccer, everybody internationally knows the rules of the game. But in the game of global economic competitiveness, the rules are changing, we don't control the rules. And maybe its time for the U.S. to understand the new rules. And adopt those modifications to our current laws and perspective that allow us to play the game with the greatest amount of competitiveness. We are still a great nation, the very laws and rules of the games that we developed over the years that are our strength, are today hindering us from continuing to be a world dominant player in this game. So I suggest that maybe its time we are as what everyone else is doing on technology transfer, and that 1) link our technology development to industry needs, and 2) review our economic laws and regulations and make them conform to the new laws of the World.

Dick Lopatka: I like to introduce an idea which is in a way a simple solution and in another way is very, very, difficult to do. That would be the notion of a lead agency for critical technologies. We have heard a lot of good technology described in various agencies, but clearly the uncomfortableness with the level of coordination and potential redundancy keeps coming out. We still lack a critical mass or major effort in the given areas. Within the current structure of agencies, there could be designated a lead agency for a particular technology. This lead agency wouldn't do all the work. The technology could be best developed in a other supporting agencies, but this lead agency would carry forward quite a few of the notions that were already put on the table.

Be responsible for the networking. Be responsible for the small business element, identifying charters and roles, doing the market research, looking at how proposal are made and submitted, doing the tech transfer studies. The lead agency would work beyond its primary mission, would play an interagency role in terms of leading the field in terms of a particular topic and would be responsible for orchestrating the national lab in industrial efforts. Maybe we could go faster in a mode where we don't introduce a new organization and a new structure, but simply try to find a way that we can allow a dual role within the agency systems we already have.

Michael Cronin: I really like the last progression of comments that have rolled up to me. I also agree that we probably slide backwards in international competiveness until a new order emerges in the USA.

From a small company's perspective the down-sizing of the defense companies along with aerospace leave a big hole, because they were the test sites and nurturing companies for some of our best ideas.

To explain - when a breakthrough in a high tech product such as a cision guided welding robot is first piloted, we do not look for a small or medium sized company to buy the first one. Instead we would approach a GE, GD, Rockwell, or United Technology because they had the time, the staff and the vision to work around any initial bugs or product shortfalls which would stop a small company cold. A void now exists which should be filled to help us get new products debugged and to market.

One idea consists of the government setting up clearly defined lead agencies for new technologies. For example, Wright Patterson could be the composite materials lead with a charter to fund R&D, SBIR's, pilot production and university teams. In addition, the agency should organize conferences and reports and may be even sponsor consortia to develop.

As an outsider, I watched the sudden eruption of interest in high-temperature super conductivity. Although little of commercial value has yet been published I was proud of the US response to the initial discoveries. Within months we had the lead in all published articles. They came from universities, private labs and government centers, which had been supported and built by government funded research and were thus ready to respond to the unplanned requirements.

In closing, I submit we keep not only our research centers alive, but must also innovate in the methods we use to transfer and communicate the technologies we funded through.

- Lead groups by technology.
- Organize communications and conferences into industrial applications groupings.
- Continue SBIR's and other mechanisms to stimulate small companies.
- Supporting our universities as research and teaching centers of excellence.

Closing Comments by:

Bob Schwinghamer: I'd say we've made some progress here today. We've had about a dozen government agencies working together for six months, we've solicited and received the candid observations of our industrial peers, so I want to take this opportunity to thank all of our government presenters, it was a lot of work involved here, and I want to thank them sincerely, the agencies and our industrial peers for being here today. Thank you all for your attendance and participation.

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The material was presented by participating Federal organizations in four sessions on Tuesday and Wednesday (December 3 and 4), as shown in the attached Symposium brochure. A key element planned by the working team was an invited panel of eleven top industry leaders involved in advanced manufacturing (names and organizations on subsequent page). This panel attended the agency briefing sessions and then, on Thursday, December 5, discussed this technology material including suggestions to improve the technology transfer process. A luncheon was also held at the convention center on Thursday, with Mr. Tom Murrin (Dean, School of Business Administration at Duquesne University and member of President Bush's Council of Advisors) as speaker. The subject of Mr. Murrin's address was "The National Competitiveness" which was relevant to the papers on their IPE related technology, and the industry review panel discussions, along with their major points asbtracted by each panel member.

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